

STAFF REPORT

2012 NATURAL GAS RESEARCH, DEVELOPMENT, AND DEMONSTRATION REPORT



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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The Energy Research and Development Division strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

Energy Research and Development Division funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies and Advanced Generation
- Energy-Related Transportation

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

The Public Interest Energy Research Program was created in 1996 when the California Legislature enacted Assembly Bill 1890 (Brulte, Chapter 854, Statutes of 1996), California's electric utility restructuring legislation. This law required that funds be collected annually from the three investor-owned electric utilities and deposited in the Public Interest Energy Research and Development Account, to be invested by the California Energy Commission in public interest energy-related research, development, and demonstration.

Similar legislation was enacted in 2000 with Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000), which required the California Public Utilities Commission to impose a surcharge on all natural gas consumed in California to fund various energy efficiency programs as well as public interest research and development to benefit natural gas ratepayers. Assembly Bill 1002 also required the California Public Utilities Commission to designate an entity to administer the research component of AB 1002.

In 2004, the California Public Utilities Commission issued Decision 04-08-010, which designated the Energy Commission as the administrator for the research funds. The Energy Commission manages these funds through its Public Interest Energy Research Natural Gas Program. In fiscal year 2011-2012, the California Energy Commission administered \$24 million for natural gas research, development, and demonstration projects through the Public Interest Energy Research Natural Gas Program.

The Energy Commission's 2012 *Natural Gas Research, Development, and Demonstration Report to the Public Utilities' Commission* highlights project successes and benefits, and covers completed projects and current California Public Utilities Commission natural gas funded research from July 1, 2011, through June 30, 2012.

Keywords: California Energy Commission

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EXECUTIVE SUMMARY

Natural gas, a critical resource for California's long-term energy future, satisfies more than one-third of the state's total energy demand. Almost half of California's natural gas consumption is used to generate electricity, while the remainder is used mainly for firing industrial processes or by the residential and commercial sectors for space and water heating. Emerging transportation technologies — such as natural gas-fueled vehicles — will add to California's natural gas consumption.

Natural gas-related energy research benefits California's economy, environment, and ratepayers by developing technologies, tools, methods and insights that increase energy efficiency, reduce pollution, and reduce greenhouse gas emissions. Consistent with its statutory purpose, the Energy Commission acts on behalf of the people of California when providing Public Interest Energy Research (PIER) Program funding to California researchers. These researchers include small businesses, universities, California-based national laboratories, utilities, energy companies, and private research organizations. By selecting and coordinating research among these organizations, the Energy Commission maximizes the effectiveness of the program.

The PIER Natural Gas (PIER NG) Program fills a critical role. It conducts public interest research to fill gaps not adequately addressed by competitive or regulated markets. Often, this research is not addressed due to perceived high-risk by the market place, even though the energy research may significantly benefit California's natural gas ratepayers when successful. The PIER NG Program uses two interrelated structural elements that provide value to the public — strategic partnerships and impartial evaluation of technologies and projects. Successful partnerships sustained on both the state and national levels, combined with the impartial evaluation of proposed research projects, helps avoid research duplication, builds on previous successful work, generates new ideas, leverages investments, and ensures that PIER NG projects provide benefits to the state's energy ratepayers.

Numerous PIER projects, some highlighted in this report, will provide lasting benefits to California's economy and natural gas ratepayers. For example, PIER-funded research led to pipe insulation requirements for the 2013 Residential Building Energy Efficiency Standards. These requirements were adopted by the Energy Commission on May 31, 2012, and will take effect on January 1, 2014. This change will save California ratepayers an estimated 8.2 million therms over a six-year period and reduce ratepayer bills by approximately \$7.9 million. Additional benefits include reduced greenhouse gas emissions, greater customer satisfaction and reduction in water use. Savings to Californians will continue to increase as future PIER-funded work is incorporated into the state's building and appliances standards.

By addressing energy efficiency and renewable and clean distributed resources, the natural gas research plan follows the state's "loading order" for satisfying energy demand. The Energy Commission is committed to being a responsible steward of the PIER NG Program. This stewardship is illustrated by the Energy Commission's strict adherence to both statutory direction and the state's energy policies. For example, energy efficiency research projects address the following state policies and goals — the California Public Utilities Commission's

(CPUC) *Energy Efficiency Strategic Plan* and the California Energy Commission's *Integrated Energy Policy Report (IEPR)*; Governor Brown's Clean Energy Jobs Plan; and Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009), which seeks to increase energy efficiency in existing buildings.

Renewable energy research accelerates the adoption of clean alternatives to conventional natural gas resources and technologies. These research projects address a number of renewable energy generation and greenhouse gas reduction goals, including those in Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006), the Global Warming Solutions Act of 2006 (AB 32). California's Renewable Portfolio Standard (as mandated by Senate Bill 1078 [Sher, Chapter 516, Statutes of 2002] and Senate Bill 107 [Simitian, Chapter 464, Statutes of 2006]) is one of the most aggressive in the United States. The goals of this standard were expanded by SBX1-2 (Simitian, Chapter 1, Statutes of 2011, First Extraordinary Session), which aims for 33 percent of generation to be provided by renewable resources by 2020.

Transportation research addresses the policy goals for alternative fuels use — specifically, conventional motor fuels replacement by 9 percent in 2012, 11 percent in 2017 and 26 percent in 2022.

Projects funded with NG funding are consistent with the annual budget plans and policy objectives approved by the CPUC. These projects are listed in the appendix. The PIER NG Program is organized around these natural gas research policy objectives:

- Improve industrial, commercial, residential, and transportation energy efficiency
- Accelerate the adoption of clean alternatives to conventional natural gas resources and technologies
- Improve natural gas system and infrastructure performance and reliability
- Reduce the environmental footprint of California's natural gas system

The *2012 Natural Gas Research, Development, and Demonstration Report* describes PIER NG-funded RD&D from July 1, 2011 – June 30, 2012. It outlines the Energy Commission's strategic vision for future natural gas RD&D needs.

This year's update contains the following sections:

- Chapter 1 – *Introduction*. Provides an overview of the natural gas research program. Highlights the strategic vision of public interest natural gas research and development. The fiscal year 2011-12 budget was allocated according to this vision.
- Chapter 2 – *Natural Gas Research Project Benefits*. Provides examples of natural gas-funded research that has resulted in measureable energy savings and/or other value.
- Chapter 3 – *Natural Gas Project Selection and Projects Funded*. Details the scoring and selection process for PIER projects and features examples of projects that were approved in FY 2011-12. A list of solicitations anticipated for 2012-13 is also included.
- Chapter 4 – *Benefits Assessments*. Highlights the method for assessing statewide ratepayer benefits for the PIER NG RD&D projects.
- Appendices

CHAPTER 1:

Introduction

History

Recognizing the importance of natural gas as a critical energy resource for California, Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000), directed the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California. This surcharge is used to fund a range of public benefit activities designed to increase natural gas end-use efficiency. The statute also allocated funding to public interest research for the benefit of California natural gas ratepayers. AB 1002 also required the CPUC to designate an entity to administer the research program.

In the CPUC Decision 04-08-010, the Energy Commission was designated as the administrator of the new Public Interest Energy Research Natural Gas Program (PIER NG Program), beginning in 2005. The Energy Commission used internal tools and processes already in place for the PIER Electricity Program (Assembly Bill 1890, Brulte, Chapter 854, Statutes of 1996). Using PIER's information management system and established administrative processes, the Energy Commission was able to provide automation services for fund encumbrance monitoring, agreement development and awarding, invoicing, project tracking, and project reporting capabilities. The use of the existing information management system and administrative processes helped to control the PIER NG Program's overall administrative costs.

The PIER NG Program has since been updated by Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006), which changed how the natural gas research funds are encumbered and managed.

Decision 04-08-010 also required the Energy Commission to submit annual reports that provide information on costs, balances of approved project budgets and expenses, benefits and progress of R&D projects.¹ This year is the seventh annual report, covering the 12-month period of Fiscal Year 2011-2012 (beginning on July 1, 2011 and ending June 30, 2012) to satisfy the decision requirements.

PIER Natural Gas Research Meets Policy Objectives

As the primary energy policy agency, the Energy Commission is the author of the state's guiding energy policy document, the biennial *Integrated Energy Policy Report (IEPR)*. The *IEPR* evaluates overall supply and demand trends for electricity, natural gas, and transportation fuels in California, as well as issues associated with energy infrastructure, efficiency, reliability, and cost. Based on these assessments, the *IEPR* recommends energy policies to the Governor. Energy Commission RD&D efforts identify new energy resources and provides new technologies, tools, standards, and protocols to help implement California's energy policies. The *IEPR* articulates state energy policy and informs the Commission's PIER Program portfolio.

¹California Public Utilities Commission, Decision 04-08-010 (August 19, 2004), <http://docs.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/39314.htm>.

The Energy Commission's natural gas research is driven by CPUC energy policies identified in Decision 04-08-010, *California Energy Efficiency Strategic Plan*, *Energy Action Plans*, the *IEPR*, the *Bioenergy Action Plan*, and the *State Alternative Fuels Plan*.²

The PIER NG Research portfolio reflects the state's energy policies and legislative direction. For example, energy efficiency research projects address the following state policies and goals — the CPUC Energy Efficiency Strategic Plan and Energy Commission's *IEPR 2009* (sets zero net energy goals for residential buildings by 2020 and commercial buildings by 2030), Governor Brown's Clean Energy Jobs Plan and AB 758 (increase energy efficiency in existing buildings), and AB 32 (reduce greenhouse gas production). Transportation research addresses the policy goals for alternative fuels use — conventional motor fuels replacement by 9 percent in 2012, 11 percent in 2017, 26 percent in 2022 — and seeks to achieve the maximum feasible improvements in vehicle efficiency by reducing the total energy needed to power transportation in California.

Additionally, renewable energy research seeks to accelerate the adoption of clean alternatives to conventional natural gas resources and technologies. Renewable energy research addresses a number of renewable energy generation and greenhouse gas reduction goals, including those in AB 32. California's Renewable Portfolio Standard (as mandated by SB 1078 and SB 107) is one of the most aggressive in the United States. The goals of this standard were expanded by *SB X1-2* (Simitian, Chapter 1, Statutes of 2011, First Extraordinary Session), which aims for 33 percent of generation to be provided by renewable resources by 2020.

PIER Natural Gas Research Investment Plan

In creating the investment plan and its research priorities, the Energy Commission received input from experts in energy and environmental research, research organizations, the state's investor-owned gas utilities, state agencies and other interested parties. We coordinate with the California Air Resources Board (ARB) to complement their research and development and avoid any duplication.

The NG Research Plan follows the state's "loading order" for new energy resources, led by energy efficiency and renewable and clean distributed resources, and energy-related transportation research, which addresses policy goals for deploying sustainable fuels and improving vehicle efficiency as stipulated in the *State Alternative Fuels Plan*.

The PIER NG research investment plan addresses the following four research areas and a small grant program that supports the early development of promising new energy technology concepts:

² *California Energy Efficiency Strategic Plan*: www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp/,
Energy Action Plan: www.energy.ca.gov/energy_action_plan/index.html,
Integrated Energy Policy Report: www.energy.ca.gov/energypolicy/index.html,
Bioenergy Action Plan: www.energy.ca.gov/bioenergy_action_plan/index.html,
State Alternative Fuels Plan: www.energy.ca.gov/ab1007/index.html

Improve industrial, commercial, residential, and transportation energy efficiency

These projects identify and develop opportunities to achieve greater near-term and long-term energy efficiency benefits with both existing and market-ready technologies. These areas include improved efficiency of hot water generation and distribution systems; food service operations; heating and building envelope systems; and demonstration of emerging technologies for industrial applications.

Accelerate the adoption of clean alternatives to conventional natural gas resources and technologies

Ongoing research into renewable technologies and the eventual deployment of market-ready renewable natural gas alternatives could substantially reduce natural gas demand. Key projects in this area include the development of energy-efficient, cost-effective combined heat and power and RD&D projects that assist in the evolution of alternative fuels that reduce natural gas consumption and greenhouse gas emissions while assisting economic development in California.

Improve natural gas system infrastructure performance and reliability

The safety and security of California's natural gas infrastructure are important priorities for the Energy Commission. Working with the CPUC, the Energy Commission addresses these challenges by supporting RD&D projects that assess the current state of technology and practices, identify emerging technologies that enhance natural gas pipeline integrity and safety, and assess residential customer behavior toward advanced customer technologies.

Reduce the environmental footprint of California's natural gas system

The core initiatives include assessing the impacts of global climate change on the natural gas system; developing strategies to reduce direct and indirect greenhouse gas emissions associated with natural gas; and developing solutions to reduce the impacts of natural gas production, distribution, storage and use on air quality, biological diversity, land use, public health, and water quality.

Energy Innovations Small Grants Program

This program provides research grants to businesses, nonprofit organizations, individuals, national laboratories, utilities, academic institutions, and other qualifying entities for research that establishes the feasibility of innovative natural gas energy concepts. The program supports the early development of promising new energy technology concepts.

Budget Plan Summary

In FY 2011-2012, the California Energy Commission administered \$24 million for natural gas RD&D projects through the PIER NG Program.

Administration expenses for FY 2011-2012 were allocated for program staffing. PIER currently has 14 staff positions funded with natural gas funds. A breakdown of the FY 2011-12 PIER NG Program budget plan by the research areas is displayed in Table 1.

Table 1: FY 2011-12 PIER Natural Gas Program Budget Plan Summary

Research Area	Approved FY 2011-12 Budget Plan
Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency	\$8.75 million
Accelerate the Adoption of Clean Alternatives to Conventional Natural Gas Resources and Technologies	\$7.25 million
Improve Natural Gas System Infrastructure Performance, Reliability and Safety	\$1 million
Reduce the Environmental Footprint of California's Natural Gas System	\$3 million
Energy Innovation Small Grants	\$1.50 million
Program Administration	\$2.50 million
TOTAL	\$24 million

Source: California Energy Commission

Coordinated Energy Partnerships

The Energy Commission is committed to forming effective partnerships in energy RD&D. The Energy Commission, as the CPUC-designated administrator for the PIER NG Program, coordinates and oversees funding with a variety of California researchers from diverse communities, including small businesses, universities, the California-based national laboratories, California investor-owned utilities, energy technology companies, and various advocacy groups. The Energy Commission creates and sustains these partnerships, both statewide and nationally, and coordinates PIER-funded natural gas research among these organizations.

National coordination and partnership efforts help avoid research duplication, build on successes, generate new ideas, leverage investments, and attract new funding to ensure that PIER maximizes the tangible benefits to California's ratepayers. In these efforts, the Energy Commission coordinates with the US Department of Energy (DOE), energy experts from a multitude of other states, Standards Development Organizations (SDOs), ratepayer and consumer advocacy groups, and other energy experts. These efforts qualify California to be the national leader in the energy research and technology implementation sectors.

Natural Gas and Electricity Synergies in California

The Energy Commission leverages the links between natural gas and electricity RD&D in a systems-based approach to advancing science and technology. For example, electric research on sensors originally developed for determining the condition of electric underground cable may also be used to find welding defects in natural gas pipelines. This complementary electric research led to a natural gas research project that will use the technology advancements to sense

natural gas pipeline defects. The PIER NG Program is now conducting important research to maintain safety and reliability of California's natural gas delivery system that leverages previous PIER electricity program-funded projects.

By coordinating natural gas and electricity RD&D efforts, the Energy Commission also leverages funding, expands partners, and shares knowledge to meet California's energy goals and increase benefits for all California ratepayers. For example, integrating direct natural gas applications with electricity energy efficiency improvements results in a reduction of total energy consumed and saves ratepayers money on their total natural gas and electricity bills.

CHAPTER 2: Natural Gas Research Project Benefits

Project Benefit Highlights

This chapter highlights some completed and ongoing projects that are producing significant value toward resolving California's energy issues. Additionally, Appendix A includes estimated energy benefits for selected projects to approximate the potential value for research projects that prove to be successful. Additional benefits estimations are conducted on an ongoing basis as described in Chapter 4. As these analyses are completed, more projects will be added to the Table in Appendix A.

The following three major California ratepayer benefits categories have been identified from the activities of the PIER NG program — economic, environmental and security. Economic benefits are primarily lower energy costs. Environmental benefits include reduced impacts from global climate change, reduced health risks related to poor indoor and outdoor air quality, and reduced environmental impacts from energy generation. Security benefits include the development and maintenance of a reliable and safe natural gas production and delivery system.

The following project summaries, listed by research area, are from recently completed or active natural gas projects that have shown either promising or significant results.

Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency

Carbon Dioxide-Based Industrial Laundry Machine

Contract Number: PIR-10-017

Contractor: CO2Nexus Inc.

PIER Amount: \$396,200

Co-funding: \$850,000

Term: October 2010 to March 2014

Issue: The commercial laundry industry has long been one of the major water consumers in California, using millions of gallons of potable water each year. While the industry has implemented water efficiency measures, until now there have been no outright substitutes introduced that offer environmental, performance and cost benefits over water. The energy and environmental impacts of implementing technologies that do not use water as a cleaning solvent are

Figure 1: CO2Nexus's Carbon-Dioxide Laundry Machine



Source: CO2 Nexus Inc.

enormous, including reductions of daily water consumption and wastewater treatment and disposal costs. Additionally, substantial energy savings can result from reduced hot water and steam use during the cleaning cycle and the elimination of the textile-drying step.

Project Description: This project will build the first commercial liquid/supercritical carbon dioxide textile cleaning machine. The purpose of this project is to document and validate:

- Real world cleaning performance across different industrial and commercial textiles, fabrics and surfactant formulations.
- Machine operating specifications, including energy consumption, cycle time, operability and workflow, component reliability, sterilization and disinfecting capabilities.
- Benchmarking of all relevant performance and cost criteria vs. incumbent water-based machines.

For this project, San Diego Gas & Electric and Southern California Edison have agreed to help measure and verify energy savings, while the Los Angeles Department of Water and Power will help measure and verify water savings. The demonstration site is ARAMARK's clean-room service facility in the Los Angeles area. The machine has been installed and was commissioned in October with test garments to ensure proper operation of the machine. Staff training and process optimization will occur in November. The first garment loads will be washed in December, and the project team will commence field-testing energy and water consumption.

Project Benefits: This technology is applicable to a wide variety of end users including industrial laundries and textile cleaning, prisons, nursing homes, universities, military bases and hotels. California has more than 8,000 such facilities. Assuming a 5 percent market penetration, this technology has the potential to save 264 GWhr, 20 million therms and more than 600 million gallons of water.

Improving Efficiency of Spark Ignited, Stoichiometrically Operated Natural Gas Engines

Contract Number: PIR-08-023

Contractor: Sturman Industries

PIER Amount: \$997,696

Co-funding: \$230,401 from Sturman

Term: June 2009 to March 2012

Issue: The key difference between stoichiometric-burn and lean-burn internal combustion engines is that the former operate at air-to-fuel ratios just sufficient to completely burn all the fuel supplied, whereas lean-burn engines operate with considerable excess air. These two combustion approaches lead to differing mechanical and emissions performance characteristics that significantly affect capital and operating costs and regulatory compliance.

Currently, spark-ignited stoichiometric natural gas engines with cooled exhaust gas recirculation (to reduce oxides of nitrogen [NO_x] formation) operate at brake thermal efficiencies up to 37 percent at full speed and load. By comparison, lean-burn natural gas engines with cooled exhaust gas recirculation under full speed and load conditions can achieve brake thermal efficiencies as high as 42 percent. This difference in efficiency results in a 12.5 percent higher fuel consumption for the stoichiometric scenario. However, lean burn engines

cannot use a low-cost, three-way catalyst for emission control, and a selective catalyst reduction system is necessary to achieve ARB 2007 compliance, adding significant capital and operating costs to the engine as well as logistics problems for both mobile and stationary power applications. Recent research has therefore focused on improving brake thermal efficiencies of spark-ignited stoichiometric platforms that employ conventional three way catalysts.

Project Description: The Sturman team developed a high-speed digital hydraulic valve actuation system coupled with microprocessor based controls to improve the performance of spark-ignited stoichiometric engines with exhaust gas recirculation and three way catalysts to more closely approach that of the lean burn option. The valve system and controls were fitted to a Cummins ISX15 natural gas engine along with an appropriate hydraulic supply system. By making these modifications and then controlling the timing and duration of valve operation, researchers were able to improve brake efficiency by:

- Eliminating throttling losses
- Operating at higher compression ratios
- Operating at higher expansion ratios

Project Benefits: Through optimization of valve control, Sturman was able to achieve a composite brake thermal efficiency of more than 40 percent and brake specific fuel consumption was reduced by as much as 18 percent from the baseline. With improved intake valve timing and employing a three-way catalyst and high pressure exhaust gas recirculation, the Cummins ISX15 platform demonstrated compliance with the ARB's 2007 emissions regulations for stationary applications. With full market penetration, the efficiency improvements from this technology package are expected to meet ARB's 2007 regulation and offer potential cost savings of \$9.7 million per year by reducing fuel consumption and carbon dioxide emissions by 71 million therms per year and 433,000 tons per year, respectively.

Figure 2: Natural Gas Engine



Source: Sturman Industries

Residential Hot Water Distribution System Enhancements

Contract Number: 500-06-029

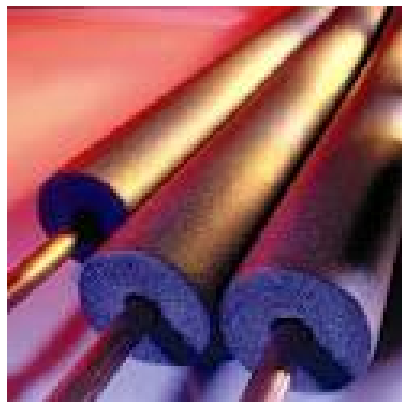
Contractor: Heschong Mahone/Dr. Carl Hiller

PIER Amount: \$1,429,841

Co-funding: \$31,000 (in-kind services) from Heschong Mahone

Term: March 2007 to March 2010

Figure 3: Residential Pipe Insulation



Source : EuroACE

Issue: In 2010, the California residential sector used nearly 5 billion therms of natural gas³. Natural gas is used by 85 percent of the water heaters in California households.⁴ As a result, natural gas for water heating constitutes approximately 40 percent of residential natural gas consumption or about 2 billion therms annually.⁵ Improvements in end use efficiencies in residential water heating distribution can yield huge natural gas savings along with reductions in water consumption, wastewater treatment energy needs, and reductions in greenhouse gas emissions.

Project Description: Dr. Carl Hiller conducted research on hot water heating and piping distribution. A variety of heat transfer tests, conducted under various conditions and on a

variety of materials and pipe sizes, showed significant savings by adding insulation to buried and unburied hot water pipes $\frac{3}{4}$ inch in diameter and larger.⁶ This research led to a 2013 *Residential Building Energy Efficiency Standard* (Title 24, part 6) requiring that insulation be used on hot water residential piping systems $\frac{3}{4}$ inch in diameter or larger.⁷ The new standard will take effect on January 1, 2014.

³ http://www.eia.gov/naturalgas/annual/pdf/table_032.pdf

⁴ US Energy Information Administration, *Residential Energy Consumption Survey*, Table HC8-11. Approximately 12.1 million households have water heating of which natural gas is used 10.3 million or 85 percent. <http://www.eia.gov/consumption/residential/data/2009/#undefined>

⁵ See page 5. <http://www.energy.ca.gov/2007publications/CEC-500-2007-105/CEC-500-2007-105.PDF>

⁶ PIER Final Report (in review) for Contract 500-06-029

⁷ http://www.energy.ca.gov/releases/2012_releases/2012-05-31_energy_commission_approves_more_efficient_buildings_nr.html

Project Benefits: The cumulative savings for the period 2014 to 2020 is over 8,200,000 therms along with a reduction of more than 50,000 metric tons of greenhouse gas.⁸ Assuming an average natural gas cost of \$0.96 per therm for residential customers, these water heating efficiencies can save Californians about \$7,900,000 over this period and approximately 1.3 billion gallons of water.⁹

Accelerate the Adoption of Clean Alternatives to Conventional Natural Gas Resources and Technologies

Production and Conditioning of High Sulfur Biogas for Fuel Cell Combined Heat and Power Generation

Contract Number: PNG-07-002

Contractor: Gas Technology Institute

PIER Amount: \$499,921

Co-funding: \$3,542,000 from Gills Onions

Term: June 2008 to March 2012

Issue: Bio-wastes represent a significant challenge to California's food processors. Industry standards for disposal vary, but may include trucking the waste back to the source for reincorporation into the soil at significant expense to the processor. An alternative approach is to use these waste products as feedstock for digesters that convert it into biogas for subsequent conversion to electricity. Fuel cells are a very promising technology for maximizing electricity production from biogas while also meeting California's stringent emissions standards. However, high sulfur content in digester gases can significantly degrade fuel cell performance and therefore represent a barrier to their wide-scale deployment.

Project Description: Gas Technology Institute researchers designed a multi-stage process for conditioning biogas from an anaerobic digester feeding two 300 kilowatt (kW) each molten carbonate fuel cells at Gills Onions, a food processing plant located in Oxnard, California. Because biogas from onion feedstock contains particularly high levels of organic and inorganic sulfur compounds, the approach employed a series of adsorbents tailored to reduce sulfur concentration to less than 100 parts per billion necessary to protect fuel cell performance. Additional stages to further concentrate, dehumidify, and compress the now 70 percent methane gas were also included.

8 Based on projections of roughly 850,000 new residential permits between 2013 and 2020 from Moody's Analytics and Bureau of the Census data and 11 therms per household of savings from 2011 CASE Report—Draft Measure Information Template—Single Family Water Heating Distribution System Improvements, Figure 8. CASE Report:
www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-05-24_workshop/review/2013_MEASURE_TEMPLATE-SF_DHW_DEG_052311.pdf.

9 Refer to Appendix A for natural gas cost justification for the residential sector. Energy Commission estimate of water savings: 8,200,000 therms x .85 efficiency x 100,000 Btu/therm/525 Btu/gallon.

Project Benefits: Gills Onions reports the environmental benefits from the anaerobic digester/biogas conditioner system to be:

Table 2: Potential Benefits to Society and Onion Industry From Fuel-Cell Adoption

Source of Savings	Savings to Gills Onions	Potential Savings for the Onion Industry ¹⁰
Electricity	\$50,000 to 60,000/month	\$500,000 to \$600,000/month
Natural Gas	112000 cubic ft/yr	1,120,000 cubic ft/yr
Diesel Fuel	40,000 gallons/yr	400,000 gallons/yr
GHG emissions of onion waste	14,500 tons CO2 equivalent/yr	145,000 tons CO2/yr

Figure 4: 110,000 Gallon Anerobic Digester at Gills Onion Facility

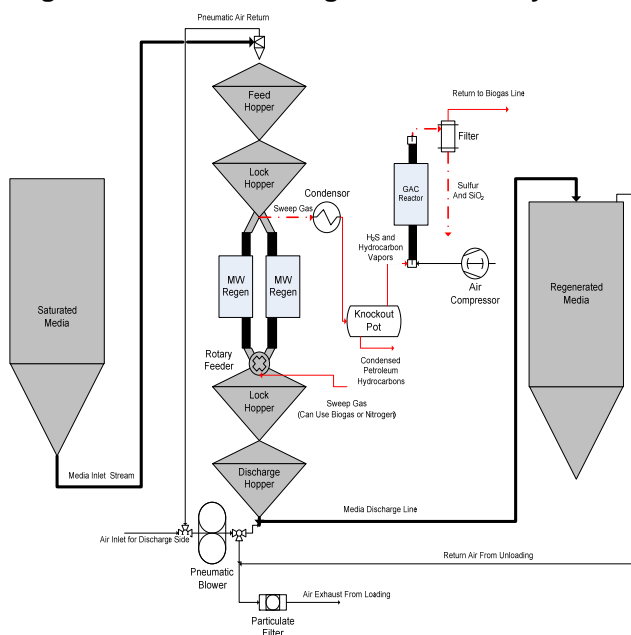


Source: Gills Onions

¹⁰ Divided Gills Onions estimated savings in each category by 0.1 to obtain potential savings for the onion industry.

Term: January 2008 to March 2012

Issue: Hydrogen sulfide (H₂S), siloxanes, and other contaminants found in biogases generated at California's dairies, landfills, and digester facilities represent a hazard to combustion equipment and post-combustion pollution control equipment. Commercially available adsorbent media for removing these contaminants tend to saturate over time and must either be replaced or undergo a regeneration process to restore effectiveness. New, replacement media are expensive and incur considerable upstream carbon dioxide and other emissions, whereas current media regeneration methods are complicated, expensive and may involve additional waste streams or require flaring.



Source: CHA Corporation

Project Description: Researchers demonstrated a biogas treatment system that combines molecular sieve media and carbon adsorbents to remove H₂S, siloxanes, and other contaminants from biogas, and incorporates a microwave-based process for regenerating saturated media and destroying the removed contaminants. Laboratory and field testing verified that application of microwave energy could restore adsorption capacity of properly formulated media over multiple cycles at a fraction of the cost of fresh media. Specific issues addressed by this project include:

- Demonstrating the readiness of microwave-based adsorbent regeneration technology for commercial applications at landfill and digester facilities.
- Demonstrating that biogas can be economically upgraded to near-natural gas quality.
- Identifying and analyzing solutions for technical and environmental barriers to commercial-scale biogas upgrading.
- Assessing the technical and economic feasibility for installing microwave systems for upgrading biogas.
- Identifying environmental and safety issues that may arise from commercial application of this technology.

Project Benefits: This project demonstrated that a biogas treatment system combining media adsorption and microwave-based technology removes H₂S, siloxanes, and other contaminants from biogas. This technology is effective and economical and can be implemented at landfills and digesters in California. This could be especially important in non-attainment areas (locality where air pollution levels persistently exceed National Ambient Air Quality Standards) in the state. California's dairies, landfills, and food processors currently discharge or flare about 40 million cubic feet per day of biomethane into the atmosphere, forgoing nearly 300-MW generation capacity. Developing this resource could reduce greenhouse gas emissions up to 6 million tons carbon dioxide equivalent per year, with an economic value up to \$112 million for electricity and carbon avoidance combined. Adoption of the technology at existing facilities will also enable operators to reduce costs related to media replacement/regeneration by as much as 50 percent.

Hydrogasification Research and Demonstration

Contract Number: 500-09-008

Contractor: University of California, Riverside

PIER Amount: \$1,000,000

Co-funding: \$281,218 UCR, \$50,000 City of Riverside

Term: June 2009 to April 2011

Issue: California generates approximately 83 million dry tons of biomass waste per year, which is mostly landfilled, burned, or polluting air and water. Considering sustainability and harvesting efficiency factors, 32.1 million tons of this biomass is available every year for fuel production. Further research and development are required to establish commercially-viable waste-to-energy conversion technologies that can simultaneously contribute to the supply of and transform waste materials into renewable transportation fuels.

Ramping up in-state biofuel production without competing with existing cropland will be difficult unless other, non-crop biomass resources can be used.

Project Description: This grant co-funded further development of a promising waste-to-energy technology known as a Steam Hydrogasification Reactor (SHR). A process demonstration unit (PDU) applying (SHR) technology was built and operated by the College of Engineering - Center for Environmental Research and Technology at its University of California, Riverside (UCR) facilities. While the technology can be used to process many forms of biomass, the primary biomass feedstock for this demonstration was biosolids from the City of Riverside wastewater treatment system, co-mingled with other biomass feedstocks, and then converted to a Fischer-Tropsch-type liquid suitable for use as diesel engine fuel. The specific objectives of this two-year project were to:

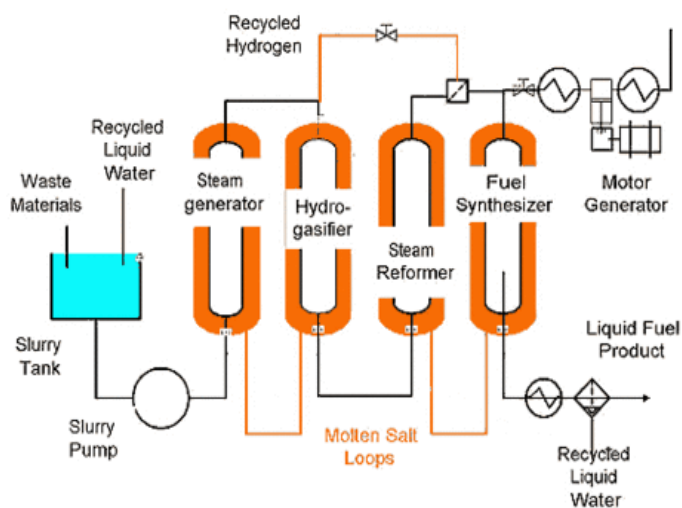
- Develop and operate a continuous feed pretreatment system that can convert biomass and biosolids feedstocks into a pumpable slurry.
- Design, construct and operate a 10 lb/hr PDU scale fluidized bed SHR that will convert the slurry feed into a high methane content synthesis gas.

- Integrate the SHR process with a gas clean-up system and a steam methane reformer demonstrating continuous synthetic gas production using the above mentioned feedstocks.
- Design a 5 tons/day pilot plant for the conversion of these feedstocks into synthetic gas.

Project Benefits: This research addressed two major barriers associated with the production of biofuels from locally available renewable biomass feedstocks, including waste:

- Preparation of the feedstocks to allow continuous feed supply to the gasifier using a relatively uncomplicated and well-known technique such as slurry pumps.
- High temperature conversion of diverse and wet feedstocks into clean synthetic gas.

Figure 6: Schematic of SHR Alternative Fuels Process



Source: UCR

This research helped move a promising technology towards commercialization. It advanced development of an innovative waste-to-fuel technology that will help California meet the State Alternative Fuels Plan's 2017 target of 11 percent alternative transportation fuels penetration.¹¹ It also contributed to diverting carbon-rich wastes from being landfilled, thereby addressing the related environmental concerns. Positive results led to additional funding directed towards scaling up the process, bringing it closer to commercial application.

The PDU was successfully designed, fabricated and operated in the gasification laboratory at UCR. Utilizing ASPEN simulation (a sophisticated chemical engineering computer application), it was found that the current SHR system in operation at UCR can produce synthetic natural gas at the rate of 11.3 therms/day from a feedstock flow rate of 0.1 ton/day. While these numbers

¹¹ *State Alternative Fuels Plan*, California Air Resources Board/California Energy Commission, CEC-600-2007-CMF, Dec. 2007, p.6

reflect an early pre-commercial stage of development, they demonstrate that the system is fully functional and highly promising.

Improve Natural Gas System Infrastructure Performance, Reliability and Safety

Best Practices in Monitoring Technology

Contract Number: 500-10-044

Contractor: Center for Information Technology in the Interest of Society (CITRIS)

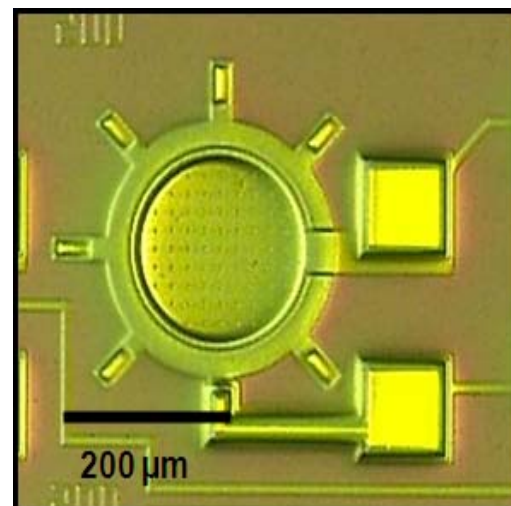
PIER Amount: \$478,857

Term: June 2011 to January 2014

Issue: The safety and security of California's natural gas pipeline infrastructure are important priorities for the state, particularly the prevention of catastrophic events, such as the San Bruno pipeline explosion in September 2010. Utilities are required to implement integrity management practices and verify record keeping of pipeline data regarding installation, material composition, and strength characteristics. However, to enhance the practices of operators, improvements to technologies used to inspect and monitor natural gas pipelines are needed. Improved technologies will help to ensure the safety and security of California's natural gas transmission and distribution system, easing heightened public concern.

Project Description: The Center for Information Technology in the Interest of Society (CITRIS) is developing innovative monitoring technologies using micro-electro-mechanical systems (MEMS) and laser ultrasonic testing (LUT). The MEMS sensors provide two-way communications regarding pipeline operating conditions at a low cost. Use of MEMS enables sensing technologies that measure pressure, flow rate, and water content to be integrated. Defects in the pipeline wall can be effectively identified and measured using LUT technology. Properties of the pipeline that can be evaluated using this technology include detection and measurement of stress corrosion cracks, thickness changes due to internal and external corrosion, weld quality, and mechanical properties such as fracture toughness. Prototypes of both technologies will be developed and tested by CITRIS researchers.

Figure 7: MEMS-Based Pressure Sensor



Source: Center for information Technology in the Interest of Society

Project Benefits: The MEMS technology will provide operators a more accurate picture of the overall pipeline status through two-way communication of pipeline operational parameters at more frequent intervals. The low cost of the sensors will allow them to be deployed more frequently throughout the pipeline network. LUT technology will allow multiple properties of the pipeline wall to be evaluated in a single inspection run, minimizing downtime associated with inspection. The LUT device can be mounted on existing pipeline crawlers, reducing the

time needed to bring the technology to market. Work performed in this project will provide tools to increase situational awareness and better inspect pipelines for defects, allowing potential problems to be identified and mitigated. Deployment of the developed technologies will provide tools to enhance the safety of the overall natural gas pipeline infrastructure.

Best Practices in Monitoring Technology

Contract Number: 500-10-050

Contractor: Gas Technology Institute

PIER Amount: \$480,000

Term: July 2011 to June 2013

Issue: A complex network of pipelines, many of which travel under areas of high population, transmit and distribute natural gas supplies throughout California. The pipelines have both varying material composition and installation dates, making integrity management a difficult, laborious task. Various inspection technologies exist to monitor pipelines and detect flaws, though improvements are necessary to enhance operator's ability to maintain a safe underground pipeline network.

Figure 8: Explorer Pipeline-Inspection Crawler



Source: Carnegie Mellon University

Project Description: The Gas Technology Institute (GTI) is researching natural gas pipeline inspection technologies used throughout the world, and identifying those not yet used in California. From the assessment, a catalogue of available technologies will be created to assist utilities to select the appropriate tools to inspect and monitor pipelines. A gap analysis report will serve to identify technologies that are available, yet not currently used in California. Emerging technologies will also be identified that may provide benefits to pipeline infrastructure in the near term. The final product will be a plan that will recommend specific technologies and the actions necessary to implement them in a timely and cost-effective manner.

Project Benefits: The overall status of natural gas pipeline inspection technologies will be assessed, and those that will provide the most benefits to California's natural gas pipeline integrity management practices will be identified. The catalogue of available technologies will provide operators a valuable reference in selecting the best inspection technology to use on the pipelines they manage. Existing, as well as emerging, technologies that can meet state assessment and monitoring needs will be identified, and a plan will be developed to use these technologies in California's natural gas pipeline infrastructure.

Reduce the Environmental Footprint of California's Natural Gas System

Atmospheric Measurements and Modeling for Verification of AB 32-Mandated GHG Emissions Reductions

Contract Number: 500-08-019

Contractor: Lawrence Berkeley National Laboratory

PIER Amount: \$505,000

Term: April 2009 to June 2012

Issue: Assembly Bill 32 (AB 32) requires that greenhouse gas (GHG) emissions in California be reduced to 1990 levels by 2020. The natural gas system in California is one of the main sources of methane (CH_4), a potent greenhouse gas. Nationally, natural gas systems represent the single largest contributor to methane emissions from all industries. Under the California Air Resources Board's (ARB) cap-and-trade program, natural gas fuel providers will need to purchase allowances or offsets. An environmentally sound cap-and-trade program requires the best characterization of emission sources as possible. Current inventory and model-based estimates of CH_4 emissions, including emissions from the natural gas system, are uncertain because many of the factors controlling emissions are poorly understood or not very well quantified. Atmospheric measurements and modeling may provide an independent method to quantify local and regional CH_4 emissions from California and to confirm the estimates in the current official GHG inventory maintained by ARB. This project was closely coordinated with ARB, given its prominent role in implementing AB 32.

Figure 9: Instruments Attached to Sutro Tower in San Francisco and KCRA's Tower in Walnut Grove



Source: Marc Fischer and the Lawrence Berkeley National Laboratory Research Team.

Project Description: This project was the second phase of a long-term PIER-funded study that began in 2006 using atmospheric methods to try to verify the current estimation of GHG emissions in central California. In the first phase, the research team attached instruments to measure emissions to two communication towers, one site located in San Francisco and the second site located in Walnut Grove in Sacramento County. In the second phase, two more years of measurements were taken, formal estimates of the errors associated with the transport models using measured wind velocities and boundary layer heights were created, and the use of flask samples was investigated to characterize nitrous oxide emissions and determine if near real-time measurements are necessary. Also, measurements of carbon dioxide at Trinidad Head, a coastal site, were added to better characterize the transport of pollution from the California coast to its interior. Using inverse modeling, the researchers took the atmospheric measurements from the towers and the information about emissions transport and estimated GHG emissions from different areas.

With the conclusion of the last project, this study has provided the first indirect quantification of annual cycles for all major GHG emissions from central California. The study found that, based on multi-year measurements from central California, differences of actual emissions from inventory estimates vary by GHG type, as follows:

- Fossil-fuel carbon dioxide consistent with ARB inventory to within +/- 10 percent
- CH₄ greater than ARB inventory by factor 1.6 +/- 0.2
- N₂O greater than ARB inventory by factor 2.7 +/- 0.5
- Halocarbon HFC-134a smaller than ARB inventory by factor of 0.6 +/- 0.1

Researchers concluded that, if these results hold for other regions of California, non-carbon dioxide emissions may constitute 20 percent of total California GHG emissions. The findings from this research project, if confirmed with further analyses and measurements, will assist in policy decisions designed to reduce GHG emissions in California.

Project Benefits: This project addresses the state's need for reliable measurement of man-made sources of GHG emissions. Results of this study suggest that estimates of methane and nitrous oxide emissions may be considerably under-estimated. The data collected under this project and additional measurements targeting the natural gas system should enable more accurate quantification of fugitive methane emissions from the natural gas system. ARB is already using this information to determine what emissions sources should be better quantified and have implemented similar measurements at some of their air quality monitoring stations. These will complement the measurements taken by the project research team.

Climate Change and Sea-Level-Rise: Implications for the California Coast

Contract Number: 500-06-002

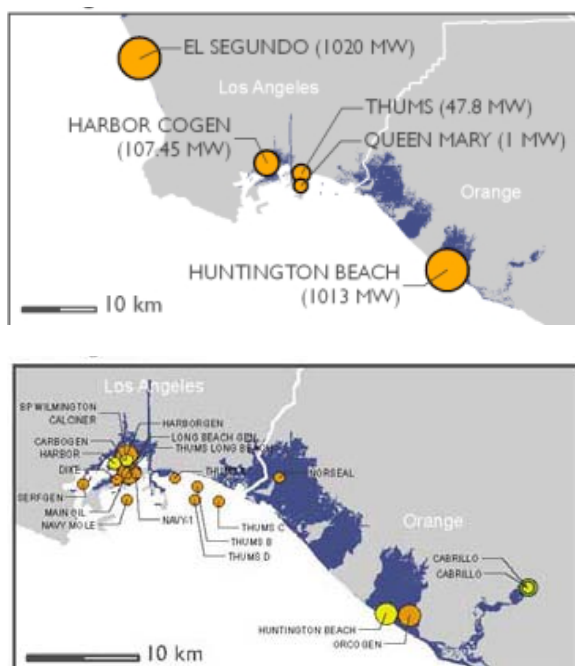
Contractor: University of Florida

PIER Amount: \$599,625

Contract Term: September 2006 to December 2011

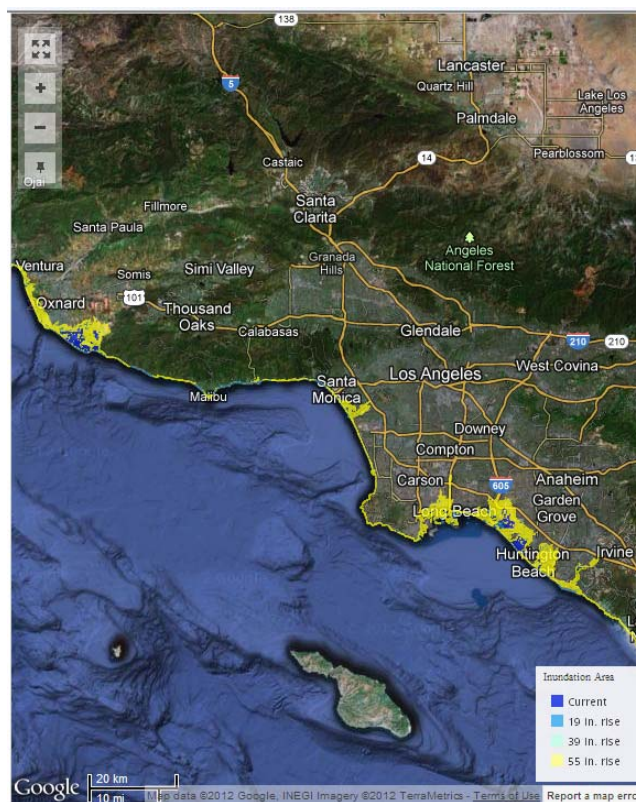
Issue: Climate change poses a challenge to the future of California's coast and energy infrastructure. California's long coastline is home to many thermoelectric power plants, substations, transmission and distribution lines, and gas storage facilities and pipelines which are vulnerable to sea-level-rise and increased flooding and inundation risk. A PIER-funded study concluded that by the end of this century, 25 coastal power plants are potentially at risk from coastal flooding with a 1.4 meter sea-level rise. The study also estimates that 86 coastal substations are threatened with inundation. Most of these substations are built to serve local power loads. Any climate-related risk to the substations will pose a risk to the associated load as well.

Figure 10: Southern California Coastal Areas and Power Plants Vulnerable to a 100-year Coastal Flood With a 1.4 meter Sea-level-rise



Source: Sathaye, Jayant, Larry Dale, Peter Larsen, Gary Fitts, Kevin Koy, Sarah Lewis, and Andre Lucena. 2012.

Estimating Risk to California Energy Infrastructure From Projected Climate Change. California Energy Commission. Publication Number: CEC-500-2012-057.



Source: <http://cal-adapt.org/sealevel/>

Waves, currents, and storms are the primary climatic forces that erode the coast. It is likely that the future climate will include changes in storminess and higher sea level. Both sea-level-rise and storminess have severe consequences for beaches, coastlines, and coastal structures, including power plants and other energy ancillary facilities such as distribution lines and

natural gas pipelines. Effective planning for the future of California's coast needs to draw on climate models that predict these scenarios and coastal change models that predict the coast's response.

Project Description: Improving our understanding of how climate change may affect coastal and near shore processes is critical to assessing the vulnerability of energy infrastructure, including power plants and natural gas pipelines in California's coastal zone. This project developed physical based procedures for a quantitative analysis of coastal processes along the Southern California Bight, an area stretching from Point Conception in Santa Barbara County to the Mexican border. As shown in Figure 10 an earlier study has identified over 8,000 MW of coastal power plants in this area that are vulnerable to a 100-year coastal flood with a 1.4 meter sea-level-rise.

Results from the modeling and analyses indicate that due to the geographic location of southern California, climate change-driven wave field alterations will have a significant effect on coastal erosion and deposition which could affect coastal energy infrastructure. These impacts need to be anticipated and prepared for in future management of coastal areas, including the protection of energy infrastructure.

Project Benefits: Due to the proximity of load centers and cooling water sources, important energy facilities occur along California's coast. Scientifically robust estimations of sea-level-rise and coastal evolution will contribute toward sound adaptation strategies that mitigate and protect coastal power plants, natural gas facilities, and other coastal energy infrastructure from the impacts of climate change and, in turn, California's ratepayers and the economy.

CHAPTER 3:

Natural Gas Research Project Selection and Projects Funded

This chapter explains how PIER projects are developed, selected, and scored, and identifies projects that began in FY 2010-11, including ongoing and completed projects that support the Energy Commission's strategic public interest natural gas RD&D areas:

- Improve industrial, commercial, residential, and transportation energy efficiency.
- Accelerate the adoption of clean alternatives to conventional natural gas resources and technologies.
- Improve natural gas system and infrastructure performance and reliability.
- Reduce the environmental footprint of California's natural gas system.

Further delineations of key research areas, or sectors, are defined within individual research objectives, indicating the broad spectrum of public interest RD&D projects funded. These projects illustrate the symbiotic relationship between natural gas and electricity research, leading to increasing overall energy efficiency. Also included are examples of forthcoming research projects/solicitations and areas for future RD&D investment.

Budget Plan Update

The Energy Commission provided to the CPUC *The Natural Gas Research, Development, and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2011-12*, which established the direction and budget for research and development activities that also provide benefits for California's natural gas ratepayers. The Energy Commission was authorized to administer \$24 million for RD&D natural gas projects through the PIER NG Program over a two-year funding period. The Energy Commission expects to fully expend the remaining budget allowance of \$15 million for new awards by June 30, 2013.

Planning Avoids Duplicative Research

When planning research, Energy Commission staff evaluates all technology and program options to help determine funding priorities and bring to market energy technologies that provide environmental and economic benefits to California ratepayers. Consulting with ARB and other government agencies, utilities, research scientists from California's universities and national laboratories, public advocacy groups, and representatives of the general public, PIER staff strives to improve transparency of research priorities and increase stakeholder input, thereby avoiding duplication of resource efforts and ensuring the relevancy of funded projects.

Over the years, the PIER Program has established research centers throughout California, forming interagency agreements with State and University campuses and laboratories. These centers provide the unique ability to establish long-term research capabilities in an organized and structured manner that is critical in the evolution of emerging technologies from the

concept and research phases toward commercialization. Also, when these centers are formed in a university environment, the multi-year funding allows the university to attract top quality professors, students, and researchers. It is more difficult to obtain these research workforce quality benefits when an effort is funded yearly or on a project-by-project basis.

Projects using PIER funding must meet the following criteria:

- Support state energy policy goals
- Result in tangible benefits to California electric and natural gas ratepayers
- Address energy research gaps
- Does not duplicate previous research
- Help resolve implementation barriers
- Demonstrate a cost-effective energy technology or measure
- Has the potential to transform the energy market

Project Scoring and Selection Process

Natural gas R&D funds are typically awarded competitively through grants (Program Opportunity Notice) or solicitations (Request for Proposals). A competitive solicitation is a public request for proposals to provide services, a specified product, and/or solve a defined problem under an agreement.

PIER-funded solicitations are required by Assembly Bill 2267 (Fuentes, Chapter 537, Statutes of 2008) to give priority to California-based entities (CBEs). A CBE is a business that has either its headquarters or an office in California and substantially manufactures the product or performs the research within California. Our research solicitation process includes requirements that: a) a minimum of 60 percent of the funds be awarded to CBEs and 60 percent of the PIER program investment is spent in California; b) applicants demonstrate methods for controlling their overhead and administrative costs; and c) demonstration projects to be in investor owned utility service areas.

All proposals received on or before the solicitation due date that meet minimum administrative requirements are evaluated, scored and ranked by an evaluation and scoring team (scoring team), based on the scoring criteria detailed in the solicitation.

Proposals that meet the minimum scoring criteria are identified, and any preference points are added (for example, disabled veteran businesses). The scoring team prepares a Notice of Proposed Awards (NOPA) package, which summarizes the evaluation results and rationale for the recommended selections

After the NOPA is approved, it is posted on the Energy Commission website. All funding recommendations and agreements are considered for approval by the full Commission at a public business meeting.

Projects Funded in Fiscal Year 2011-12

In fiscal year 2011-12, \$25.8 million in NG funding was awarded to begin 24 new PIER NG research projects. Table A-1 in Appendix A of this report provides a list of the natural gas funded research projects expended from fiscal years 2010-11 and 2011-12 PIER NG Program budget plans. The projects highlighted below reflect a sampling of these efforts.

Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency

Reducing Waste in Residential Hot Water Distribution Systems

Contract Number: 500-10-052

Contractor: Lawrence Berkeley National Laboratory

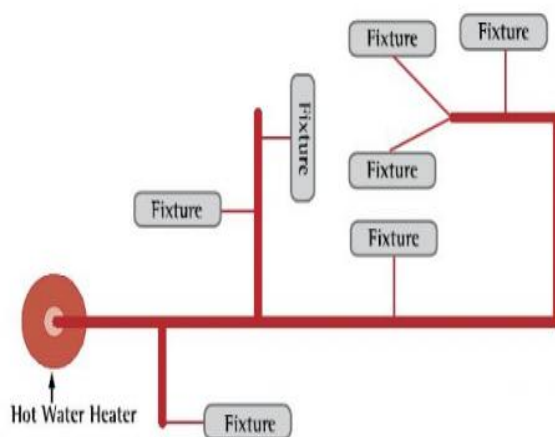
PIER Amount: \$280,000

Co-funding: \$0

Term: June 2011 to December 2014

Natural gas fuels nearly 85 percent of California's residential water heating. About 570 million cubic feet of natural gas is used each day for water heating in California homes. Little is known about how people actually use hot water, but anecdotes indicate that as much as \$1,000,000,000 annually of California water and fuel is wasted as people run water, waiting for it to get to usable temperature, which, after brief usage, then cools down in the pipes. Much of this waste is related to the hot water distribution systems designed by plumbers.

Figure 11: Conventional Hot Water Distribution System



Source: https://buildingsfieldtest.nrel.gov/hot_water_distribution

This project will collect and evaluate information that will lead to improved standards for residential plumbing construction. The research will include a field study of actual water use in at least 25 California houses and develop estimates for the efficiency of the hot water systems based on the measured usage. Field performance data from this project will also contribute to the development of simulation tools. The results of this study will be presented in papers and will contribute to California Title 20 and 24 efficiency standards. This project will lead to improved residential hot water systems that can reduce both energy and water use.

Automated Sealing of Building Envelopes With Adhesive Aerosols

Contract Number: 500-08-042 (2)

Contractor: University of California, Davis - Western Cooling Efficiency Center (PI: Dr. Mark Modera)

PIER Amount: \$300,000

Co-funding: \$0

Term: 31 months (the project started in September 2012 and will end in March 2015)

Leaky building envelopes are major sources of energy loss from buildings and can result in increased cost for heating and cooling. For existing and new buildings, sealing building envelopes manually is challenging, labor intensive, and very costly. A simple and inexpensive method of sealing is needed to improve building energy efficiency and reduce energy consumption. This project will develop and demonstrate a system that uses an aerosol-based sealant mist to seal the many leaks in the building envelope. This technology works fast and doesn't require a contractor to crawl through attics or punch holes in walls.

Because heating and cooling loads are directly affected by infiltration rates, reducing infiltration to controlled levels will reduce natural gas used for heating and cooling buildings, thereby reducing energy costs. Additional benefits include improved comfort and potentially lower heating and cooling equipment requirements.

Figure 12: Preparing Room for Aerosol Sealing



Source: Western Cooling Efficiency Center

Digester Repowering Demonstration Project

Contract Number: PIR-11-026

Contractor: UTS Bioenergy, LLC

PIER Amount: \$ 1,933,551

Co-funding: \$ 607,722

Term: July 2012 to March 2015

Municipal wastewater treatment is a necessity in North America to protect clean water supply and to promote the overall health of the environment. Measures have been taken to ensure effluents from municipal wastewater treatment, including liquid and bio-solids discharges are of high quality and are environmentally beneficial. Missing from this however, is the focus on the energy required to treat municipal wastewater with the processes, design and infrastructure seen today in North American wastewater treatment plants.

This project demonstrates the installation of an anaerobic digester retrofit package that, through a process called "recuperative thickening," increases the percentage of solids in the digester by a factor of 2 to 3 times and facilitates the mixing and heating necessary to provide for increased production of biogas. Biogas is rich in methane and, when cleaned, can be used as fuel and converted into electricity or pipeline quality renewable natural gas. In addition to producing enough energy to cover all of the plants' current electricity needs, this project will offset the need to purchase natural gas associated with heating the anaerobic digester.

Figure 13: Sludge Thickener



Source: UTS Bioenergy, LLC

Accelerate the Adoption of Clean Alternatives to Conventional Natural Gas Resources and Technologies

Alternative Fuels Natural Gas Infrastructure Compatibility

Contract Number: 500-11-015

Contractor: The Regents of the University of California on behalf of the Riverside campus

PIER Amount: \$1,200,000

Co-funding: \$0

Term: June 2012 to June 2014

Figure 14: California Natural Gas Pipeline



Source: UCR

California and the rest of the nation are dependent upon an extensive and pervasive network of transportation, storage, and distribution systems for oil and natural gas fuels. These systems evolved over many decades around reliability criteria associated with petroleum-based fuels. As California transitions to greater use of alternative fuels, such as renewable natural gas, there are a number of barriers to address. These alternative fuels — which come from a variety of sources, through diverse pathways and technologies, in various formulations — carry

new and unexpected trace impurities that could affect the pipeline infrastructure. Currently, there is limited knowledge and understanding on how the new alternative fuels will impact the safety, operations, and reliability of the existing natural gas and other fuel pipeline infrastructure. This project is a pipeline and infrastructure safety, reliability, and operability assurance program for liquid and gaseous transportation fuels. The effects of various contaminants not normally found in conventional oil- and gas-derived fuels will be addressed. Benefits include the advancement of the commercial availability of renewable natural gas and a reduction of California's dependence upon imported motor vehicle fuels.

Fuel-Flexible, Hybrid CHP at San Bernardino Municipal Water Department

Contract Number: PIR-11-028

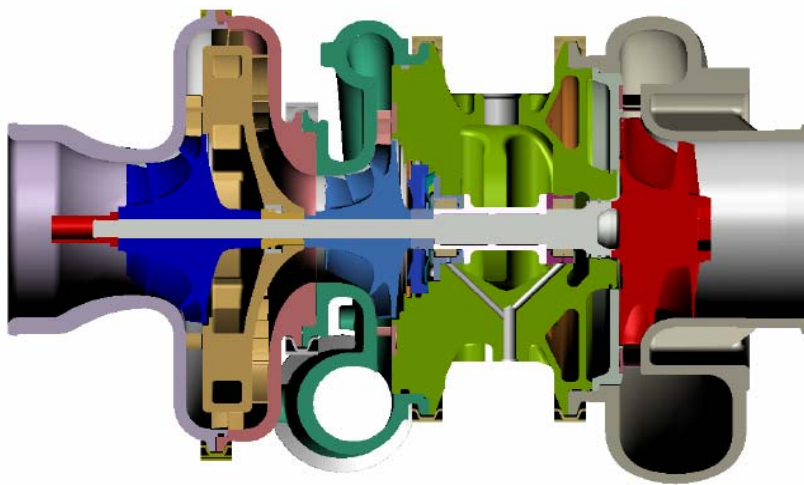
Contractor: Gas Technology Institute

PIER Amount: \$1,767,185

Co-funding: \$870,388 from GTI, Vronay Engineering, and Alturdyne

Term: July 2012 through March 2015

Figure 15: Twin Compressor Turbocharger



Source: Caterpillar

Researchers at the Gas Technology Institute will develop and demonstrate a technology for bringing biofuels-based combined heat and power (CHP) facilities into compliance with new emissions rules without resorting to expensive fuel preconditioning. The proposed approach will take advantage of significant reductions in NO_x and hydrocarbon emissions that can be attained by enriching the hydrogen content of the fuel by partially oxidizing a portion of the mixture prior to combustion in the prime mover. The hybrid system will integrate a fuel processor for reforming hydrogen gas from bio-methane and a commercially available turbocharger with an existing 750-kWe internal combustion engine-based CHP system at a San Bernardino Municipal Water Department wastewater reclamation plant. The system is expected to achieve ultra-low emission performance on par with similar natural gas-fired systems. Reducing the need to precondition the fuel will lower the cost of using internal combustion engines in biogas-fueled combined heat and power systems, thereby addressing a significant barrier to market acceptance and deployment. Current wastewater treatment operators will gain another option for bringing their facilities into compliance with the stricter air emission regulations, allowing them to continue to benefit from biogas that would otherwise be flared into the atmosphere.

Production of Substituted Natural Gas From the Wet Organic Waste by Utilizing PDU-Scale Steam Hydrogasification Process

Contract Number: 500-11-004

Contractor: The Regents of the University of California on behalf of the Riverside campus

PIER Amount: \$649,214

Co-funding: \$200,000

Term: October 2011 to October 2012

This agreement continues the development of a promising new waste-to-energy technology known as the steam hydrogasification reactor (SHR) process, which was demonstrated successfully for the production of clean syngas at the process demonstration unit (PDU) scale by UC Riverside, developed through an earlier PIER award. The PDU scale bubbling fluidized bed reactor is now being extended to produce renewable natural gas. SHR shows strong potential to enable the efficient conversion of high moisture biomass (including agricultural waste and municipal sewage sludge) into renewable natural gas. The ability to handle and use high water content is significant because it eliminates the costly and energy-intensive process of drying the biomass before undergoing thermochemical processing into fuel.

This project represents a good example of establishing long-term research capabilities that enable the evolution of emerging technologies toward commercialization.

Figure 16: Synthetic Fuel Production Apparatus



Source:
University of California Riverside

Novel Flex Fuel Oxidation for Distributed Generation

Contract Number: PIR-11-016

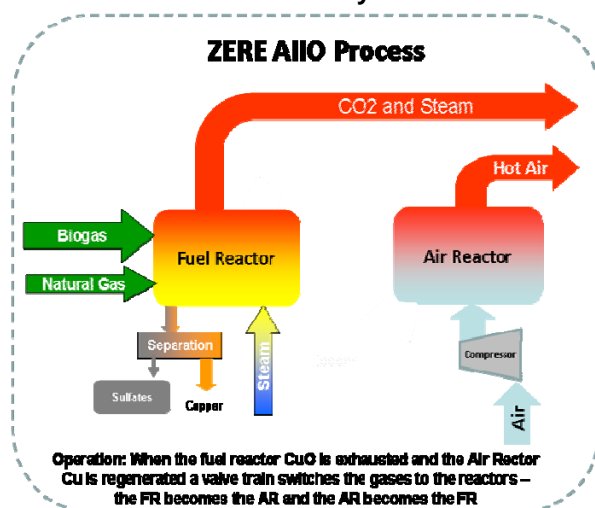
Contractor: ZERE Energy and Biofuels, Inc.

PIER Amount: \$998,346

Co-funding: \$437,500 from ZERE, and the International Copper Association

Term: July 2012 through March 2015

Figure 17: Proposed Air-independent Internal Oxidation System



Source: ZERE

ZERE will develop and build a prototype, fuel-flexible combined heat and power system based on a unique combustion strategy. ZERE's patented Air Independent Internal Oxidation (AIIO) is a procedure for generating zero-emissions electric power and process heat. Biomass waste is oxidized internally using a solid stage metal oxide, capturing nearly 100 percent of the fuel energy, forming no pollutants. The system will run on natural gas and untreated biogases, energy sources that burn cleaner than traditional fossil fuels. Because the fluidized bed in the reactor will capture oxides of sulfur and silicon, combustion products of unconditioned biogas will become safe for use in rotating machinery, significantly reducing the cost of using these fuels. In

addition, since the only combustion products that leave the reactor are steam and carbon dioxide, a simple condensation process can be employed to separate the carbon dioxide for sequestration or industrial uses, if so desired. If successful, AIIO-based systems offer the promise of cost-effective heat and electricity using a variety of fuels with near-zero pollution released to the atmosphere.

Data Center Demonstration With Combined Heat and Power Technology

Contract Number: PIR-11-014

Contractor: Contractor Name: ICF International

PIER Amount: \$974,179

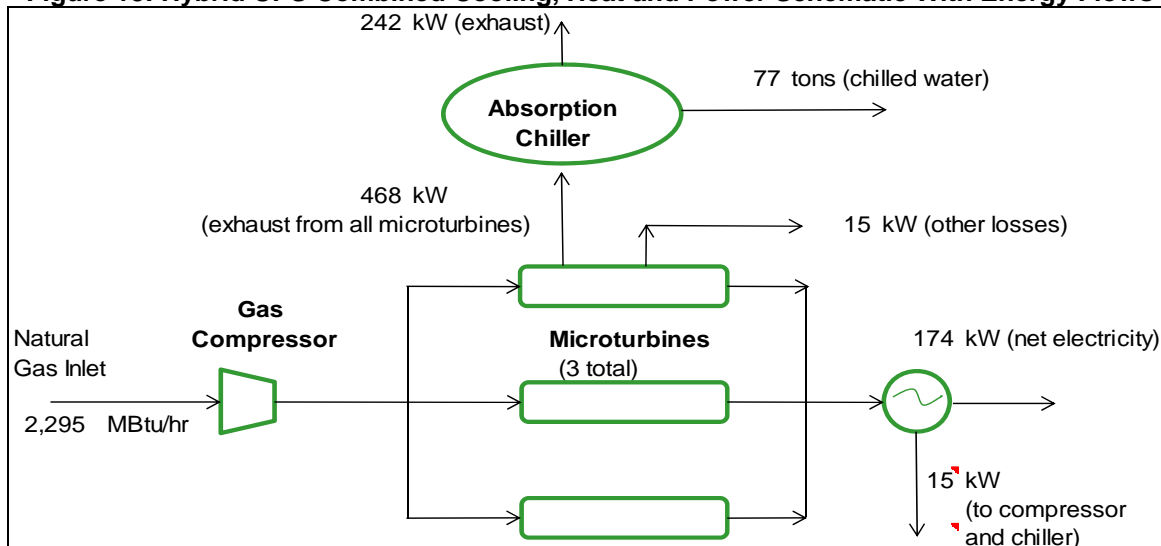
Cofunding: \$504,189

Term: June 2012 to March 2015

ICF International will use a hybrid Uninterruptible Power Supply (UPS) microturbine to provide power quality during energy fluctuations and a power source in case of grid failure. This is done by installing inverter modules to a standard Capstone C65 microturbine to provide AC power connections to both the data center load and the grid. The use of a microturbine to provide both power quality and back-up power will remove the UPS off the grid and will run on either natural gas or renewable energy sources. The clean exhaust from the microturbine powers an absorption chiller that replaces an electric chiller powered by the grid to provide

chilled water for data center cooling. The expected energy savings is up to 41 percent of a standard UPS, and the pollutant reduction is 80 percent NO_x as compared to using utility power.

Figure 18: Hybrid UPS Combined Cooling, Heat and Power Schematic With Energy Flows



Source: ICF International

Novel Hydrodynamic Separation Technology for Wastewater Treatment

Contract Number: PIR-11-006

Contractor: Palo Alto Research Center

PIER Amount: \$1,001,899 (\$973,089 Natural Gas)

Co-funding: \$380,817

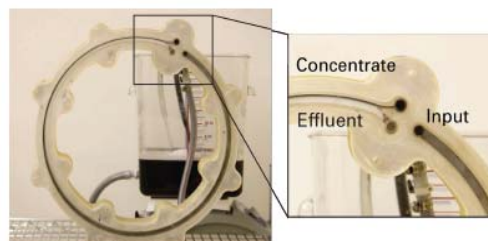
Term: June 2012 to March 2015

Secondary treatment in wastewater facilities includes

activated sludge processing (ASP), which is the aeration of organic material in wastewater after primary treatment. The ASP process uses as much as two-thirds of the total energy required for wastewater treatment, making it the most energy intensive operation at a wastewater facility.

The hydrodynamic separation (HDS) technology is a modular, compact solids separation unit that can increase the removal of suspended solids after primary treatment, thereby removing organic material that requires treatment in the ASP step. These organic solids, which are more difficult to treat in the ASP, are good biodegradable material for anaerobic digestion to increase generation of renewable energy. The HDS technology is a carefully designed channel system that diverts particles above a cutoff size into a curved channel where they are removed, dewatered, and sent to an anaerobic digester. The modular nature of the technology can be adjusted to any facility size, be installed with very few changes to existing facility equipment, and works well with combined sewer and storm drain facilities.

Figure 19: A 10-LPM HDS lab prototype



Source: PON-11-501 Proposal Documents

Tests have shown the HDS technology can remove 70 percent of the particles not removed in primary treatment, which would equate to a 50 percent reduction in energy for aeration in the secondary treatment step. The project will also increase the generation of on-site renewable energy by increasing the amount of biodegradable material in the anaerobic digester. The increased biogas produced can be used to produce electricity for on-site use and reduce the natural gas used for heating of the digesters. Excess electricity can also be exported back to the grid and could lead to better overall economics of the system.

Reduce the Environmental Footprint of California's Natural Gas System

Assessment of Potentially Deleterious Effects of Geologic Carbon Sequestration Operations on Groundwater Quality

Contract Number: 500-11-024

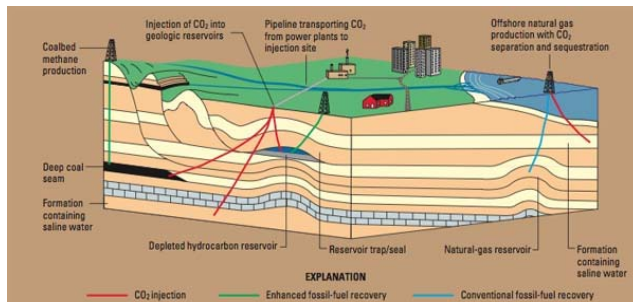
Contractor: Lawrence Berkeley National Laboratory

PIER Amount: \$600,000

Cofunding: \$0

Term: June 2012 to March 2015

Figure 20: Schematic of Carbon Storage, Also Known as Carbon Sequestration



Source: United States Geological Survey

carbon dioxide into deep geologic formations that will keep the carbon dioxide from returning to the surface. However, between 30 percent and 40 percent of California's water supply comes from groundwater. Before industrial-sized carbon storage projects begin, research into the possible effects — for example, leakage — on groundwater supplies is needed to ensure that contamination is avoided.

This project will focus on sediment and water quality issues specific to California and will assess the potential impacts of carbon dioxide leakage into the underground water supply to determine its viability as a mitigation process. The project goal is to close the information gap associated with carbon dioxide underground storage. Laboratory and computer modeling results will provide the support needed for effective decision-making regarding the risk of water resource degradation caused by long-term carbon dioxide storage activities. Project results will directly guide California policy with regard to carbon dioxide mitigation efforts, and aid in achieving the AB 32 goal of reducing greenhouse gas emissions to 1990 levels by 2020. Future research will benefit from the conclusions of this project and help protect the environment and the health of Californians.

The combustion of NG is a major source of greenhouse gas emissions in California.

Mitigation of greenhouse gas induced climate change is an important factor contributing to the health and prosperity of California. Natural gas-fired power plants have the ability to capture carbon dioxide that would otherwise be released into the atmosphere. After capture, the question then becomes an issue of storage. One proposed solution, carbon sequestration, is to inject the

Low-Cost High Sensitivity NOx Sensors

Contract Number: 500-11-022

Contractor: Lawrence Livermore National Laboratory

PIER Amount: \$600,000

Cofunding: \$0

Term: June 2012 to March 2015

During the years 2010 to 2018, electricity consumption in California is projected to grow at a rate of 1.2 percent annually, with peak demand projections at 1.3 percent. Much of the power for this increase in electricity consumption may come from natural gas-fired distributed generation (DG) projects. Distributed generation employs small-scale technologies to produce electricity close to the consumer. However, the potential for increases in emissions of criteria air pollutants accompanies the increase in DG. Low-cost, highly sensitive sensors are needed to measure very low emission levels of nitrogen oxides (NOx), which is a concern because most Californians live in areas that are classified as non-attainment for the federal ozone standards. Existing NOx sensors lack the accuracy and precision needed to help control or monitor emissions from small natural gas-fueled engines.

Figure 21: Low-Cost NOx Sensors Can Help Control Emissions from Distributed Generation



Source: University of California at Riverside, Center for Environmental Research and Technology

Researchers at the Lawrence Livermore National Laboratory will build upon their success in developing automotive NOx sensors by customizing them for stationary distributed generators. By employing a low-cost NOx sensor that can be used to monitor and control NOx emissions, DG facilities can ensure emissions are within current regulatory limits. This will help reduce the environmental impacts of DG and help in the siting of new DG, benefiting California ratepayers.

Prototype and Demonstration of Membrane Processes for Natural Gas Dehydration

Contract Number: 500-98-014

Contractor: Haiqing Lin, Membrane Technology and Research, Inc.

PIER Amount: \$94,995

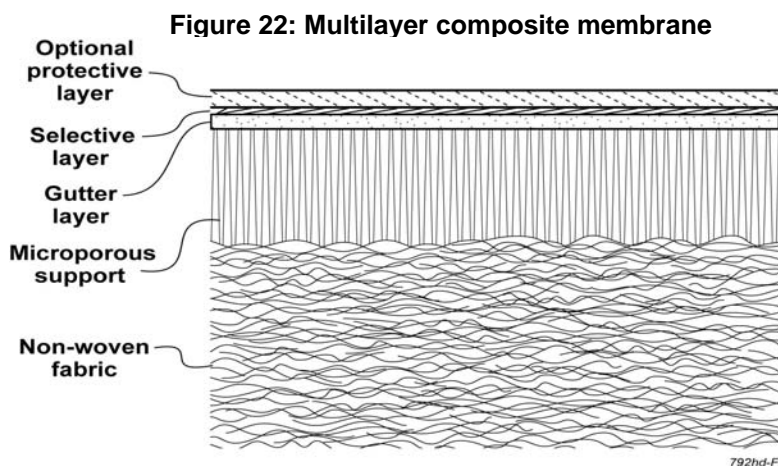
Cofunding: \$86,793

Term: January 2012 – September 2012

Issue: All natural gas must be dried before it enters the national distribution pipeline, to control corrosion and prevent formation of solid hydrocarbon/water hydrates.

Currently, glycol dehydrators are widely used; approximately 36,000 units are in service in the United States, of which about 10 percent are in California. Glycol absorbs water, and water desorption is achieved by distillation. However, glycol also absorbs volatile organic compounds (VOCs) from the raw natural gas streams. The vent streams from dehydrators have become a major source of environmental emissions of VOCs. A typical glycol-based unit discharges more

than 4 tons per year of various organic pollutants. Controlling such emissions to meet the clean air regulations imposed by the California Environmental Protection Agency is becoming one of the largest environmental challenges facing the natural gas industry.



Source: Membrane Technology and Research, Inc.

Project Description: The project goal is to determine the feasibility of using new membrane processes for natural gas dehydration, leaving VOCs in the natural gas product streams, and thus producing zero emissions of VOCs.

Project Benefits: Benefits resulting from adopting the proposed membrane dehydration systems will be realized by California natural gas producers and consumers in at least three ways:

- *Emissions reduction.* VOC emissions from glycol dehydrators in California amount to about 5,000 tons/yr. The new membrane systems provide a cleaner, safer means of dehydrating natural gas with essentially zero VOC emissions. It allows VOCs to remain in the natural gas stream for subsequent combustion rather than venting through the glycol dehydration process.
- *Natural gas production – capital cost savings.* Based on comparative cost data, capital replacement costs for all glycol dehydrators in California are estimated at about \$500 million. The same number of membrane systems at the same average size would cost about \$380 million resulting in an overall savings of \$120 million (~25 percent) over the replacement lifetime of the dehydration equipment.
- *Natural gas production – operating cost savings.* Membrane systems typically provide up to 20-40 percent operating cost advantages over competing conventional “wet chemistry” separations. Membrane systems are inherently more compact, less complex, and more reliable, with less need for operator attention and no chemical consumption.

Plans for the Future

PIER Natural Gas Program's Anticipated Funding Opportunities

The PIER Natural Gas Program will continue to implement natural gas funded research consistent with the FY 2011-12 Program Plan and Budget. Information about potential upcoming funding opportunities will be posted to:

http://www.energy.ca.gov/contracts/pier_upcoming.html as it becomes available. Information posted on this page is subject to change.

Funding opportunities in the form of solicitations are public requests for proposals to provide services, a specified product, and/or solve a defined problem under contractual agreement. The Energy Commission uses Program Opportunity Notices for grants and Request for Proposals (RFP) for contracts.

The following Table 3 lists upcoming PIER Natural Gas Program funding opportunities for fiscal year 2012-13. To receive an e-mail when solicitations are released, interested parties can subscribe to the list server located at <http://www.energy.ca.gov/research/>.

Table 3: PIER Natural Gas Program Funding Opportunities, Fiscal Year 2012-13

Tentative Schedule	Potential PIER Natural Gas Focus Area and Solicitation Name	Summary of Proposed Natural Gas Research	Estimated NG Budget (million)
Fall 2012	Energy Efficiency: Building Energy Efficiency Research and Technology Grant Program (BEERT)	Potential funding of the following research projects that reduces natural gas usage: <ul style="list-style-type: none">• Technology innovations and advancements• Support for building and appliance energy efficiency codes and standards• Cross cutting zero net energy building and low income housing demonstrations	\$9.0 NG
	Transportation: 1) Natural Gas Vehicle (NGV) Engine Development 2) Advanced Renewable Natural Gas Transportation Fuel Production	Potential funding to: <ul style="list-style-type: none">• Develop technology improvements that will expand the availability of natural gas engines and expand market for NGVs. The research aims to develop a broader range of heavy-duty NGV engine sizes for more applications.• Target novel and innovative technologies for the production of renewable gas for transportation fuel with value-added co-products and/or co-benefits that will help California meet its greenhouse gas reduction goals with new and more economically viable processes.	\$2.45 NG

Tentative Schedule	Potential PIER Natural Gas Focus Area and Solicitation Name	Summary of Proposed Natural Gas Research	Estimated NG Budget (million)
Fall 2012	Energy Technology Systems Integration: Natural Gas Pipe Line	Potential funding to: <ul style="list-style-type: none"> • Demonstrate innovative natural gas pipeline monitoring technologies that can improve data collection techniques, and ensure safety and reliability in the natural gas transmission infrastructure. 	\$2.0 NG
Winter, Spring and Fall 2012-13	Energy Innovations Small Grant Program	Potential funding to: <ul style="list-style-type: none"> • Conduct research that establishes the feasibility of innovative energy concepts. Research projects must target one of the PIER R&D areas, address a California energy problem and provide a potential benefit to California natural gas ratepayers. Maximum of \$95,000 for hardware projects and \$50,000 for modeling projects to small businesses, non-profits, individuals and academic institutions	\$1.79 NG

Source: California Energy Commission

Chapter 4: Benefits Assessment

Quantifying Benefits of Research

Three major California ratepayer benefits categories have been identified from the activities of the PIER NG program: economic, environmental, and security. Economic benefits are primarily lower energy costs. Environmental benefits include reduced impacts from global climate change, reduced health risks related to poor indoor and outdoor air quality, and smaller environmental impacts from energy generation. Security benefits include the development and maintenance of a reliable and safe natural gas production and delivery system.

PIER's benefits assessment method involves collection and evaluation of data throughout the stages of solicitation development, award, and project management. Applicants for PIER funding must demonstrate that the proposed project meets a defined market need in California, as evidenced by specific market research, surveys, or the applicant's assessment of the technology's commercialization potential. Where applicable, they must identify which policy and regulatory drivers they are complying with and how the research will fill in knowledge gaps or facilitate permitting. Applicants must also demonstrate that the proposed project would not occur without the expenditure of public dollars or that it would otherwise not occur in time to provide relevant benefits to California ratepayers. The types of information to be collected at the conclusion of the project include amount of natural gas and costs saved and other benefits resulting from the research. The final report should include an overall assessment of these benefits and future projections of venture or other capital, units sold and jobs created in California with widespread implementation.

Additionally, PIER staff performs independent analysis on market potential for selected projects. For a large group of projects such as those listed in Appendix B, PIER staff analyzes market potential, applying expert judgment where needed, to develop estimates of potential benefits that are typically more conservative than contractor-submitted estimates. For a smaller group of projects, PIER staff performs a more detailed benefits evaluation, involving extensive research and peer review. An example of such an analysis was performed for a Lawrence Berkeley National Laboratory project that involved making recommendations to improve energy and water efficiencies in residential hot water heaters and hot water distribution systems. Detailed cost and benefit calculations that involved computer simulations of homes as well as economic projections of new residential construction led to estimates of savings attributable to PIER funding that rise to \$51 million a year by 2020. This sort of analysis is labeled in the Appendix B table as a "detailed staff projection."

APPENDIX A:

NG Research Projects Approved in FY 2011-12

Table A-1: New PIER Natural Gas Funded Research Projects, Fiscal Year 2011-12 *

Agreement #	Company	Title	Amount
500-08-042	Western Cooling Efficiency Center - UC Davis	Western Cooling Efficiency Center Research	\$300,000
500-08-044	Center for the Built Environment - UC Berkeley	Advanced Building Systems Technology Development	\$300,000
500-09-042	Lawrence Berkeley National Laboratory	Healthy Homes - Exposure to Unvented Combustion Gases	\$1,000,000
500-10-052	Lawrence Berkeley National Laboratory	National Lab Buildings Energy Efficiency Research Projects	\$991,510
500-11-004	UC Riverside	Production of Substituted Natural Gas from the Wet Organic Waste by Utilizing PDU-Scale Steam Hydrogasification Process	\$649,214
500-11-014	UC Riverside	Improved Renewable Natural Gas Production by Steam Hydrogasification with Carbon Capture	\$1,400,536
500-11-015	UC Riverside	Alternative Fuels Natural Gas Infrastructure Compatibility	\$1,200,000
500-11-016	The Regents of the University of California on behalf of the Berkeley campus	Assessment of Bay Area Gas Pipeline Vulnerability to Sea Water Intrusion	\$425,000
500-11-022	Lawrence Livermore National Laboratory	Low-Cost High Sensitivity NOx Sensors	\$600,000
500-11-024	Lawrence Berkeley National Laboratory	Assessment of Potentially Deleterious Effect of Geologic Carbon Sequestration Operations on Groundwater Quality	\$600,000
500-11-027	Lawrence Berkeley National Laboratory	Evaluation of Opportunities to Mitigate Fugitive Methane Emissions from the California Natural Gas System	\$1,100,000
500-11-029	KEMA, Inc.	Technical Support for the Research and Development Division	\$495,700
PIR-11-006	Palo Alto Research Center, Incorporated	Novel Hydrodynamic Separation Technology for Wastewater Treatment	\$973,089
PIR-11-008	West Biofuels, LLC	Demonstration of Advanced Biomass Combined Heat and Power Systems in the Agricultural Processing Sector	\$2,000,000
PIR-11-014	ICF International	Data Center Demonstration with Combined Heat and Power Technology	\$974,179
PIR-11-016	ZERE Energy and Biofuels, Inc.	Novel Flex Fuel Oxidation for Distributed Generation	\$998,346

PIR-11-023	Southern California Gas Company	Combined Heat and Power with Thermal Storage for Modern Greenhouses	\$1,502,699
PIR-11-024	Maulbetsch Consulting	Wind Barriers to Mitigate Wind Effects on Air-Cooled Condensers	\$749,577
PIR-11-026	UTS Bioenergy LLC	Municipal Digester Repowering Demonstration Project	\$1,933,551
PIR-11-027	Altex Technologies Corporation	Tri-generation energy system technology (TRIST)	\$731,770
PIR-11-028	Gas Technology Institute	Fuel-flexible, hybrid CHP at San Bernardino Municipal Water Department	\$1,767,185
PIR-11-029	Gas Technology Institute	Demonstration of Waste Heat Recovery for Power Generation	\$1,733,000
PIR-11-030	Biodiesel Industries of Ventura, LLC	Demonstrate Integrated Renewable Energy Technologies for Biorefineries	\$1,829,544
PIR-11-032	Quantitative BioSciences, Inc	Algae-based Treatment of Dairy Wastewater & Generation of Renewable Energy	\$1,500,000
		Total	\$25,754,900

* The projects listed in Table A-1 reflect budgeted expenditures from fiscal years 2010-11 and 2011-12 PIER NG Program budget plans.

Source: California Energy Commission

APPENDIX B:

Technology Market Benefit Assessment

The following are unit costs and emissions used in calculating the cost savings in Table B1:

Cost Per Unit	Units	Sources
\$326,510	peak electricity cost per MW per year	CEC-200-2009-017-SD, Klein, Joel. 2009. Comparative Costs of California Central Station Electricity Generation Technologies
\$4.00	gasoline price per gallon	Estimate consistent with recent history
\$22.50	tonne CO ₂ e	ARB is expecting \$15 to \$30 per tonne, this is the midpoint
\$0.68	therms natural gas - commercial sector	Based on April 2011 Energy Commission natural gas workshop
\$0.96	therms natural gas - residential sector	Based on April 2011 Energy Commission natural gas workshop
\$0.57	therms natural gas - industrial sector	Based on April 2011 Energy Commission natural gas workshop
\$0.47	therms natural gas - generation sector	Based on April 2011 Energy Commission natural gas workshop
\$3.80	LNG price per diesel gallon equivalent	Estimate consistent with recent history
\$5.00	diesel price per gallon	Estimate consistent with recent history
\$1.20	savings per gallon of diesel replaced by LNG	Diesel price per gallon minus LNG price per diesel gallon equivalent

Emissions per Unit	Tonnes CO ₂ equivalent (CO ₂ e)	Sources
0.00530699	Tonnes CO ₂ e per therm	Converted from a calculation by ARB staff using default emission factors listed in the Mandatory GHG Reporting Regulation
0.0088	Tonnes CO ₂ e per gallon of gasoline	The number chosen depends on which vehicles are using it and also on the ethanol blend, but looking at ARB Greenhouse Gas Inventory, this is a good approximation.
0.01024817	Tonnes CO ₂ e per gallon of diesel	Calculated from CO ₂ equivalents from CO ₂ , N ₂ O, and CH ₄ used for heavy-duty trucks, per the ARB Greenhouse Gas Inventory

Source: California Energy Commission

Tables in this section describe the benefits of PIER-funded natural gas projects, numerically (Table B-1) and in words (Table B-2). Description numbers are provided so that the reader seeking explanation for the numbers in Table B-1 can check the descriptions in Table B-2.

Except where specified, estimates do not cover incremental costs to consumers. Learning curves, economies of scale, and market competition will bring costs down.

Column 7 of Table B-1 lists “Definition of Potential”, and describes the type of benefit anticipated. For example:

1% of maximum penetration	This is used where no estimate of market penetration is available, and does not imply that only 1 percent is expected.
1% of <i>State Alternative Fuels Plan</i>	This is used where no estimate of market penetration is available, and is a low estimate for what could be a valuable technology.
1% sector savings	This early stage research affected an entire sector. Here results are shown should the research ultimately result in only 1 percent savings.
Staff professional judgment	Staff based the benefits assessments upon market and product data that was available.
Detailed staff projection	Using computer modeling along with housing start projections, staff developed a detailed assessment of the impact, which ultimately affected building standards.
Order of magnitude projection	Because the research is in the early stages, staff can only provide an order-of-magnitude projection.
Contractor projection	The awardee, Gas Technology Institute, projected the market impact.
Realized in demo	The project was a demonstration, and the savings are being realized. If future market penetration has been estimated, it is provided in a separate row.
Realized in first 9 months of sales	Sales data were available for this new technology.

Some projects lack benefits estimates, and the reason will be explained in the “Definition of Potential” column of Table B-1.

Table B-1. Estimates of Project Benefits for PIER Projects Funded by the Natural Gas Surcharge, October 2012

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Engine CHP Emission Control Technology: advanced emission control system for stationary natural gas engines	CHP	General Industrial	3,169,019,944 Industrial Therms/yr	3,500,000 Industrial Therms/yr	\$1,995,000	1% of maximum penetration	\$749,013	\$371,586	Description 1
Advanced engine system for combined heat and power and combined cooling, heating and power: a 100 kW dual shell stirling engine integrated with a catalyzed flow burner designed to meet the ARB 2007 emission standards	CHP	General Industrial	3,169,019,944 Industrial Therms/yr	0	\$0	project not completed	\$249,536	\$274,060	Description 2
Energy, Economic and Environmental Performance of Dairy Bio-power and Bio-methane Systems: Anaerobic Digester Systems, Renewable Fueled CHP Systems, Bio-Methane Systems	Research or Modeling to Optimize Energy Planning Decisions	Generation: biogas	7,500,000 Generation Therms/yr	3,300,000 Generation Therms/yr	\$1,551,000	1% of maximum penetration	\$999,925	\$0	Description 3
The Advanced Natural Gas Vehicle Fuel Tank using adsorption in carbon-activated briquettes, manufactured from spent corncobs	Transportation (not biofuels)	Light-duty Vehicles	16,000,000,000 gallons of gasoline per year	29,440,000 gallons gasoline/yr	\$117,760,000	1% of State Alternative Fuels plan	\$1,000,000	\$500,000	Description 4
	Transportation (not biofuels)	Light-duty Vehicles	140,800,000 Tonnes CO2e / yr	75,131 Tonnes CO2e / yr	\$1,690,445	1% of State Alternative Fuels plan	\$1,000,000	\$500,000	Description 5

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Purification and Liquefaction of Biomethane Landfill Gas for Transportation Fuel	Biofuels	Diesel Fuel	2,590,655,088 gallons diesel/yr	2,800,000 gallons diesel/yr	\$14,000,000	realized in demo	\$992,903	\$0	Description 6
	Biofuels	Petroleum Refining to make diesel fuel	1,205,506,542 Industrial Therms/yr	127,404 Industrial Therms/yr	\$72,620	realized in demo	\$992,903	\$0	Description 7
California Transportation Fuels Crops Development and Demonstration Program	Biofuels	General Transportation	17,459,547,875 gallons of gasoline and diesel/yr	500,000,000 gallons gasoline/yr	\$2,000,000,000	order of magnitude Staff projection or professional judgment	\$993,284	\$0	Description 8
	Biofuels	General Transportation	153,644,021 Tonnes CO2e / yr	4,400,000 Tonnes CO2e / yr	\$99,000,000	order of magnitude Staff projection or professional judgment	\$993,284	\$0	Description 9
Hydrogasification Research and Demonstration: turning biomass into renewable natural gas and biofuels	Biofuels	General Transportation	0	0	\$0	early stage process research	\$994,524	\$980,953	Description 10
Life Cycle Greenhouse Gas and Energy Analyses of Production of Algae Biofuels	Biofuels	General Transportation	17,459,547,875gallons of gasoline and diesel/yr	0	\$0	research to inform policy	\$142,747	\$0	Description 11

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Algae OMEGA (Offshore Membrane Enclosures for Growing Algae): growing oil-producing algae offshore in semipermeable enclosures	Biofuels	General Transportation	17,459,547,875 gallons of gasoline and diesel/yr	0	\$0	promising game changer, too early to quantify	\$793,576	\$10,000,000	Description 12
Production of Soladiesel RD™ Cellulosic Feedstock: making alternative diesel fuel from biomass through heterotrophic algal fermentation	Biofuels	General Transportation	17,459,547,875 gallons of gasoline and diesel/yr	400,000,000 gallons diesel/yr	\$2,000,000,000	Staff projection or professional judgment	\$789,697	\$88,118	Description 13
	Biofuels	General Transportation	153,644,021 Tonnes CO2e / yr	4,099,268 Tonnes CO2e / yr	\$92,233,530	Staff projection or professional judgment	\$0	\$0	Description 14
On-Site Aerobic Fermentation of California Cellulosic Agricultural Waste into Biofuel: creating alternative fuels through a bacterial pathway	Biofuels	General Transportation	17,459,547,875 gallons of gasoline and diesel/yr	0	\$0	promising game changer, too early to quantify	\$800,000	\$650,000	Description 15
Improved Greenhouse Gases Inventory Methods for California Landfills	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	Energy: Landfills	6,300,000 Tonnes CO2e / yr	0	\$0	research to inform policy	\$399,929	\$0	Description 16
Climate Change and Sea Level Rise: Implications for the California Coast	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	Generation: Thermoelectric	10,000 MW	0	\$0	research to inform policy	\$599,625	\$0	Description 17

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Estimation of Long-Term Energy-Efficiency Potentials for California Buildings and Industry	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	Generation: Utilities	600,000,000 Tonnes CO2e / yr	0	\$0	research to inform policy	\$550,000	\$0	Description 18
Observation of Methane and other Non-Carbon Dioxide Greenhouse Gas Emissions from California	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	General Natural Gas	77,932,253 Tonnes CO2e / yr	0	\$0	research to inform policy	\$660,000	\$0	Description 19
Validation of a New Technology for Real-Time Measurement of the Isotopic Composition of Methane in Ambient Air	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	General Natural Gas	77,932,253 Tonnes CO2e / yr	0	\$0	research to inform policy	\$250,000	\$0	Description 20
California AUAV Air Pollution Profiling Study: climate change impacts and adaptation	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	Generation: Hydropower	13,057 MW	0	\$0	research to inform policy	\$698,991	\$0	Description 21
Estimation of Methane Emissions from the California Natural Gas System: GHG Inventory Methods	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	General Natural Gas	77,932,253Tonnes CO2e / yr	0	\$0	research to inform policy	\$600,000	\$0	Description 22
Improving Regional Climate Models: Aircraft Collection of Data	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	Generation: Hydropower	13,057 MW	0	\$0	research to inform policy	\$800,000	\$0	Description 23
The potential of biochar soil amendments as a carbon sequestration method in California agriculture	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	Agriculture	104,912,214 therms/yr	0	\$0	research to inform policy	\$700,000	\$0	Description 24

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Laboratory Validation of Novel Greenhouse Gas Monitoring Techniques	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	General Natural Gas	77,932,253 Tonnes CO2e / yr	0	\$0	research to inform policy	\$81,427	\$0	Description 25
Adaptation Strategies for Agricultural Sustainability in Yolo County, California	Climate Change Research to Help Ratepayers Cost-Effectively Meet GHG Policy Goals	Agriculture	104,912,214 therms/yr	0	\$0	research to inform planning	\$290,000	\$0	Description 26
Certification and Field Demonstration of a 0.2 g/bhp-hr NOx HPDI LNG Truck: Westport 15L GX Heavy-Duty LNG engine equipped with High Pressure Direct Injection (HPDI)	Transportation (non biofuels)	Class 8 Heavy Duty Vehicles	1,291,000,000 gallons of gasoline and diesel/yr	257,000,000 gallons diesel displaced by LNG / yr	\$309,428,000	Staff projection or professional judgment	\$500,000	\$691,800	Description 27
	Transportation (non biofuels)	Class 8 Heavy Duty Vehicles	2,778,381 Tonnes CO2e / yr	2,633,780 Tonnes CO2e / yr	\$59,260,043	Staff projection or professional judgment	\$500,000	\$691,800	Description 28
Natural Gas Vehicle Research: engine technology, vehicle technology, and infrastructure	Transportation (not biofuels)	Medium and Heavy Duty Vehicles (Classes 4-8)	2,351,200,000 gallons of gasoline and diesel/yr	0	\$0	developing research road map or tools	\$300,000	\$0	Description 29
Ultra-Low Emissions, 12-13 Liter Heavy Duty Natural Gas Engine Development	Transportation (not biofuels)	Class 8 Heavy Duty Vehicles	1,291,000,000 gallons of gasoline and diesel/yr	98,000,000 gallons diesel displaced by LNG / yr	\$117,992,000	Staff projection or professional judgment	\$1,000,000	\$1,390,686	Description 30
	Transportation (non biofuels)	Class 8 Heavy Duty Vehicles	13,039,100 Tonnes CO2e / yr	210,907 Tonnes CO2e / yr	\$4,745,415	Staff projection or professional judgment	\$1,000,000	\$1,390,686	Description 31

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Lower Cost High Performance and High Efficiency Pilot-Ignited Directly Injected HD Natural Gas Engine	Transportation (non biofuels)	Class 8 Heavy Duty Vehicles	1,291,000,000 gallons of gasoline and diesel/yr	26,000,000 gallons diesel displaced by LNG / yr	\$31,304,000	Staff projection or professional judgment	\$998,844	\$998,844	Description 32
	Transportation (non biofuels)	Class 8 Heavy Duty Vehicles	13,039,100Tonnes CO2e / yr	54,600Tonnes CO2e / yr	\$1,228,500	Staff projection or professional judgment	\$998,844	\$998,844	Description 33
Gas Optimized Advanced Heavy Duty Engine Concept: Development of a 13L Natural Gas Engine concept with High Pressure Direct Injection Technology	Transportation (non biofuels)	Class 8 Heavy Duty Vehicles	1,291,000,000 gallons of gasoline and diesel/yr	97,500,000 gallons diesel displaced by LNG / yr	\$117,390,000	Staff projection or professional judgment	\$999,970	\$390,259	Description 34
	Transportation (non biofuels)	Class 8 Heavy Duty Vehicles	13,039,100 Tonnes CO2e / yr	240,750 Tonnes CO2e / yr	\$5,416,875	Staff projection or professional judgment	\$999,970	\$390,259	Description 35
Improving Efficiency of Spark Ignited, Stoichiometrically-operated Natural Gas Engines: application of mobile technology to stationary natural gas engine applications with specific implementation of variable engine valve actuation	Transportation (not biofuels)	Electricity Generation - CHP Systems	354,315,000 Industrial Therms/yr	3,200,000 Industrial Therms/yr	\$54,720,000	1% of maximum penetration	\$997,696	\$230,401	Description 36
Advanced Radiant Heating, Ventilation, and Air Conditioning Systems for California Homes	NG Energy Efficiency	HVAC/Residential	22,000 GWh/yr	1,270 GWh/yr	\$157,480,000	contractor projection	\$1,989,598	\$240,432	Description 37

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
	NG Energy Efficiency	HVAC/Residential	1,665,336,317 Residential Therms/yr	94,000,000 Residential Therms/yr	\$90,240,000	contractor projection	\$1,989,598	\$240,432	Description 38
	NG Energy Efficiency	HVAC/Residential	14,845 MW	1,000 MW	\$326,510,000	contractor projection	\$1,989,598	\$240,432	Description 39
Improved Natural-Gas Fired Aluminum Smelting Burner	NG Energy Efficiency	Aluminum remelting	20,000,000 Industrial Therms/yr	1,470 Industrial Therms/yr	\$838	1% of maximum penetration	\$384,563	\$2,224,903	Description 40
Field Demonstration of Prototype Natural Gas Fired Super Boiler, demonstrated in a Food Processing Use	NG Energy Efficiency	Food Processing	62,000,000 Industrial Therms/yr	13,000 Industrial Therms/yr	\$7,410	realized in demo	\$239,969	\$319,030	Description 41
	NG Energy Efficiency	Food Processing	62,000,000 Industrial Therms/yr	3,100,000 Industrial Therms/yr	\$1,767,000	Staff projection or professional judgment	\$239,969	\$319,030	Description 42
Design and Development of Low-Cost, High-Temperature, Non-tracking Solar Collectors for food processing, and mass production	Solar-Related	Process heating, steam generation	2,693,666,952 Industrial therms/yr	1,510,000 Industrial therms/yr	\$860,700	1% of maximum penetration	\$577,563	\$816,351	Description 43

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Reduce Natural Gas Use for Industrial Process Heat using High-Temperature Parabolic Trough Solar Collectors: proof of concept solar thermal steam generation augmenting natural gas fired boiler	Solar-Related	Process heating, steam generation	2,693,666,952 Industrial therms/yr	127,000 Industrial therms/yr	\$72,390	realized in demo	\$700,000	\$995,000	Description 44
Reverse Annulus Single Ended Radiant Tube (RASERT): Advanced indirect heat natural gas fired Radiant Heat Tube to replace state of the art Single Ended Radiant Tubes	NG Energy Efficiency	Metals industry (heat processing)	74,000,000 Industrial Therms/yr	20,000 Industrial Therms/yr	\$11,400	realized in demo	\$284,969	\$171,400	Description 45
	NG Energy Efficiency	Metals industry (heat processing)	74,000,000 Industrial Therms/yr	116 Tonnes CO2e / yr	\$2,610	realized in demo	\$284,969	\$171,400	Description 46
	NG Energy Efficiency	Metals industry (heat processing)	74,000,000 Industrial Therms/yr	45,000 Industrial Therms/yr	\$25,650	1% of maximum penetration	\$284,969	\$171,400	Description 47
	NG Energy Efficiency	Metals industry (heat processing)	74,000,000 Industrial Therms/yr	230 Tonnes CO2e / yr	\$5,175	1% of maximum penetration	\$284,969	\$171,400	Description 48
High Efficiency Gas-Fired Drum Dryer for Food Applications: to replace state of the art steam pressure vessel drum dryers	NG Energy Efficiency	Food processing	62,000,000 Industrial Therms/yr	146,000 Industrial Therms/yr	\$83,220	1% of maximum penetration	\$950,458	\$561,710	Description 49

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Reducing Natural Gas Use in California Process Industries - Workshop and Roadmap Report	Research or Modeling to Optimize Energy Planning Decisions	Process heating, steam generation	2,693,666,952 Industrial therms/yr	0	\$0	developing research road map or tools	\$135,552	\$0	Description 50
Develop recommendations to improve energy and water efficiencies in residential hot water heaters and hot water distribution systems	NG Energy Efficiency	Residential water heating	2,166,000,000 Residential Therms/yr	76,826,270 Residential Therms/yr	\$50,838,787	detailed staff projection	\$1,396,000	\$0	Description 51
Super efficient natural gas fired water heating appliance initiative	NG Energy Efficiency	Residential water heating	2,166,000,000 Residential Therms/yr	20,000,000 Residential Therms/yr	\$19,200,000	1% sector savings	\$395,303	\$0	Description 52
Hot Water Distribution System Research: Multi-family hot water distribution systems, hot water piping heat loss and improved showerhead performance with less water consumption	NG Energy Efficiency	Residential water heating	2,166,000,000 Residential Therms/yr	8,600,000 Residential Therms/yr	\$8,256,000	staff projection or professional judgment	\$1,000,000	\$31,000	Description 53
Water Heating and Hot Water Usage in California Homes: test alternative storage-type gas water heaters	NG Energy Efficiency	Residential water heating	2,166,000,000 Residential Therms/yr	20,000,000 Residential Therms/yr	\$19,200,000	1% sector savings	\$1,124,000	\$0	Description 55
Unpressurized Solar Storage Tank for drain back systems	NG Energy Efficiency	Residential water heating	2,166,000,000 Residential Therms/yr	6,000 Residential Therms/yr	\$0	realized in first 9 months of sales	\$284,500	\$225,000	Description 56

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Barriers to Expansion of Natural Gas Storage Facilities in California	NG Market Efficiency	General Natural Gas: Storage Capacity	2,629,120,000 therms/yr	0	\$0	research to inform policy and planning	\$103,473	\$0	Description 57
Field Demonstration of 0.2 Grams Per Brake Horsepower-Hour NOx Natural Gas-Fired Engine that meets 2010 Nox emissions standards	Health and Environment	Class 6 through Class 8 Medium and Heavy Duty Vehicles	1,901,500,000 gallons of gasoline and diesel/yr	152,000,000 gallons diesel/yr	\$760,000,000	Staff projection or professional judgment	\$225,000	\$433,131	Description 58
	Health and Environment	Class 6 through Class 8 Medium and Heavy Duty Vehicles	19,205,150 Tonnes CO2e / yr	327,122 Tonnes CO2e / yr	\$7,360,236	developing research road map or tools	\$225,000	\$433,131	Description 59
Using Gasoline, Diesel, and Compressed Natural Gas (CNG) Vehicles, Characterize the Significance of Lube Oil in PM Formation	Health and Environment	General Transportation	17,459,547,875 gallons of gasoline and diesel/yr	0	\$0	research to inform policy	\$100,000	\$1,342,046	Description 60
Using the California Fleet, Conduct Physicochemical and Toxicological Assessment of Particulate Matter Emissions	Health and Environment	General Transportation	17,459,547,875 gallons of gasoline and diesel/yr	0	\$0	research to inform policy	\$225,000	\$452,950	Description 61
Heavy-Duty Emissions and Fuel Consumption Improvement	Transportation (not biofuels)	Class 8 Heavy Duty Vehicles	1,291,000,000 gallons of gasoline and diesel/yr	64,550,000 gallons diesel/yr	\$322,750,000	Staff projection or professional judgment	\$150,000	\$200,000	Description 62
Determining the Volatility of Ultrafine Particulate Matter Emissions from Compressed Natural Gas Vehicles Control Technologies	Health and Environment	General Transportation	17,459,547,875 gallons of gasoline and diesel/yr	0	\$0	research to inform policy	\$350,000	\$0	Description 63

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Energy and Water Recovery with Transport Membrane Condenser: The first non-boiler demonstration of Transport Membrane Condenser (TMC) technology	NG Energy Efficiency	Food processing paper drying, and chemical industries	At least 1,120,000,000 Industrial Therms/yr	420,000 Industrial Therms/yr	\$239,400	1% of maximum penetration	\$479,650	\$486,842	Description 64
Waste Heat Recovery from Corrosive Industrial Exhaust Gases: Demonstration of gas cleaning technology to allow for heat recovery from high-temperature flue gas that contains corrosive elements	NG Energy Efficiency	Aluminum remelting	20,000,000 Industrial Therms/yr	52,000 Industrial Therms/yr	\$29,640	1 percent of maximum penetration	\$490,000	\$470,000	Description 66
Natural Gas Variability in California: Environmental Impacts and Device Performance: Modeling and testing the impacts of variable natural gas supplies on end use performance, pollutant, and CO2 emissions. With the growing demand for natural gas in California, an alternative is to import LNG. A concern exists, however, about the increased use of LNG leading to pollution.	Research or Modeling to Optimize Energy Planning Decisions	Residential, commercial, and industrial sectors.	10,480,017,878 therms/yr	0	\$0	research to inform policy and planning	\$4,336,690	\$0	Description 67

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Gaseous Fuel Interchangeability Criteria Development: development and validation of design tools that describe operability and emissions impacts as fuel composition varies in diverse power generation devices such as gas turbines, boilers, and reciprocating engines	Research or Modeling to Optimize Energy Planning Decisions	General Natural Gas	12,777,867,604therms /yr	0	\$0	developing research road map or tools	\$1,132,714	\$82,000	Description 68
Healthy Homes - Exposure to Unvented Combustion Gases: develop the science to reduce health risks to the population of California from exposure to unvented residential combustion gases - residential natural gas appliances, with specific focus on unvented appliances and advanced technology water heaters	Research or Modeling to Optimize Energy Planning Decisions	Residential Natural Gas	5,095,714,851 therms/yr	0	\$0	research to inform policy	\$1,263,300	\$0	Description 69
Effect of Natural Gas Fuel Composition on Vehicle Performance and Emissions: evaluate the performance and air pollution impacts of natural gas vehicles using various unconventional natural gas blends including imported LNG	Research or Modeling to Optimize Energy Planning Decisions	Transportation: NG Vehicles	250,000,000 therms/yr	0	\$0	research to inform policy	\$400,000	\$330,400	Description 70
Potential Impacts from Geologic Carbon Sequestration on Groundwater Resources in Central Valley of California	Health and Environment	General Natural Gas	77,932,253	5,000,000 Tonnes CO2e / yr	\$112,500,000	research to inform planning	\$490,000	\$0	Description 71

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Energy Efficiency Calculator Tools: Development of Excel-based calculator tools to quantify the energy savings achieved by implementing various energy efficiency measures in process heating and steam generation	NG Energy Efficiency	Process heating, steam generation	2,693,666,952 Industrial therms/yr	160,000,000 Industrial therms/yr	\$91,200,000	Staff projection or professional judgment	\$200,000	\$219,441	Description 72
Next Generation Instantaneous Water Heater: This project sought to identify any issues with tankless water heaters and discover ways to improve the technology	NG Energy Efficiency	Residential Water heating	2,166,000,000 Residential Therms/yr	6,200,000 Residential Therms/yr	\$5,952,000	1% of maximum penetration	\$200,738	\$0	Description 74
Hybrid Optimized Tankless (HOT) Water Heater: Development of a low-cost, higher efficiency, water heater, which can be easily retrofitted for the new and replacement market	NG Energy Efficiency	Residential Water heating	2,166,000,000 Residential Therms/yr	15,000,000 Residential Therms/yr	\$14,400,000	Staff projection or professional judgment	\$200,000	\$0	Description 75
Production and Conditioning of High Sulfur Biogas for Fuel Cell Combined Heat and Power Generation: conditioning and clean-up of high sulfur biogas produced from agricultural waste through an anaerobic digestion process	Biofuels	Food Processing	62,000,000 Industrial Therms/yr	316,000 Industrial Therms/yr	\$180,120	realized in demo	\$499,921	\$3,542,000	Description 76
	Biofuels	General Industrial	3,169,019,944 Industrial Therms/yr	2,740,000 Industrial Therms/yr	\$1,561,800	1% of maximum penetration	\$499,921	\$3,542,000	Description 77

Project	Research Type	Sector/Subsector	Sector/Subsector Use Total	Estimated Potential Savings	Estimated Cost Savings (a)	Definition of Potential	Project Cost	Match Funding	Benefits Calculation Description
Reducing California Industrial Natural Gas Consumption Through Advanced Biomass Gasification: demonstration of an advanced, lower-cost molten-metal gasifier that can utilize waste biomass to create thermal energy for mid-sized industrial concerns	Biofuels	General Industrial	3,169,019,944 Industrial Therms/yr	9,690,000 Industrial Therms/yr	\$5,523,300	1% of maximum penetration	\$500,000	\$500,000	Description 78
Advanced Residential Energy and Behavior Analysis Project: residential natural gas demand forecasting models and energy efficiency programs and policies	Research or Modeling to Optimize Energy Planning Decisions	Residential Natural Gas	5,095,714,851 Residential Therms/yr	0 Residential and Commercial Therms/yr	\$0	research to inform planning	\$2,197,887	\$0	Description 79

Table B-2. Descriptions of Project Benefits for PIER Projects Funded by the Natural Gas Surcharge, October 2012

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 1	Engine CHP Emission Control Technology: advanced emission control system for stationary natural gas engines	<p>Failure to cost-effectively achieve and sustain compliance with the state and local emission standards deters the implementation of new combined heat and power in California. If compliance was attained, the technical potential for new small (< 5 MW) applications would be 10,800 MW by 2029, per CEC's CHP Market Assessment.</p> <p>At a typical capacity factor of 75%, and an overall CHP efficiency of 75%, generating those 10,800 MW using CHP rather than natural gas turbines burning alone could save 340,000 billion BTUs of energy in avoided waste heat losses, saving on the order of 18 million tonnes of CO₂.</p>	With emissions cost effectively controlled, CHP use will grow. CEC's CHP Market Assessment. projects that rich-burn engine CHP, which is prevalent in systems less than 1 MW in size, will account for roughly 1,100 MW by 2029. This translates to 35,000 billion BTUs of energy savings, comparable to 350 million industrial therms.
Description 2	Advanced engine system for combined heat and power and combined cooling, heating and power: a 100 kW dual shell stirling engine integrated with a catalyzed flow burner designed to meet the ARB 2007 emission standards	<p>The California market lacks options for small-scale CHP applications at or below 100 kW, which can contribute to energy security, grid support, and high levels of energy efficiency. Engines for CHP need to (1) produce emissions below ARB 2007 requirements, (2) maintain high efficiency, and (3) match facility electric and thermal loads.</p> <p>Energy and environment targets under AB 32 specified an additional 4,000 MW of installed CHP capacity by 2020, enough to displace approximately 30,000 gigawatt-hours of demand from other power generation sources.</p>	project not completed
Description 3	Energy, Economic and Environmental Performance of Dairy Bio-power and Bio-methane Systems: Anaerobic Digester Systems, Renewable Fueled CHP Systems, Bio-Methane Systems	<p>Producing biogas from dairy waste is a large potential source of renewable fuel in California if the energy, economic and environmental performance of these systems can be determined and effective systems can be demonstrated.</p> <p>Less than 5% of California dairy facilities produce biogas from manure for energy production. This represents only about 7.5 million therms of biogas or 36 million kilowatt hours of bio-power production.</p>	The dairy industry represents a potential to expand the portfolio of fossil-free energy in California with a potential production of 330 million therms of renewable biogas. This biogas can be converted to 290 million gasoline gallon equivalents of Bio-Methane or 1.6 billion kilowatt hours of bio-power production, offsetting natural gas. If only 1% of potential were realized, 3.3 million therms would be generated renewably. Other savings would result from reduced petroleum demand in California by using bio-methane as a vehicle fuel and/or reduced electrical grid loads from dairy facilities that employ bio-power systems.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 4	The Advanced Natural Gas Vehicle Fuel Tank using adsorption in carbon-activated briquettes, manufactured from spent corncobs	The transportation sector, responsible for nearly 40% of California's GHG emissions, is a major contributor to global warming. Emissions can be lowered using natural gas as a fuel. Unfortunately, compressed natural gas requires thick, bulky, cylindrical tanks and provides only a 200 mile range for a light-duty truck.	This research addresses absorbing natural gas in corncob briquettes to provide an extended driving range (transportation) of 300 miles via a lighter (half of the weight), smaller, flatter tank, without taking up any trunk or passenger space. The reduced weight will further increase vehicle efficiency and reduce gas consumption while making natural gas vehicles a more attractive consumer choice. The low-pressure design will also reduce fueling-station costs, for both public stations and home fueling appliances, by significantly reducing the energy needed for compression. The goal of this research is to develop and demonstrate NG storage technology that will facilitate the increase of California's use of NG as a motor fuel. NG is currently 0.6% of the state's on-road transportation fuel with a potential increase to 19% (an increase of 18.4%) by 2050, thereby displacing a significant number of gallons of gasoline that would have been used.
Description 5	The Advanced Natural Gas Vehicle Fuel Tank using adsorption in carbon-activated briquettes, manufactured from spent corncobs	Natural gas is a cleaner fuel than gasoline so enabling its use as a transportation fuel has environmental benefits.	Natural gas emits 29% less CO ₂ per mile than gasoline. Gasoline emits about 8.8 kg of CO ₂ per gallon burned, thus for each gallon avoided, .29 x 8.8 kg of CO ₂ is avoided.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 6	Purification and Liquefaction of Biomethane Landfill Gas for Transportation Fuel	State transportation energy policy has established goals to reduce the amount of petroleum derived fuel consumed in California by increasing the use of alternative fuels, increasing vehicle efficiency and reducing vehicle miles traveled. Increasing the use of alternative combustion fuels including high global warming potential landfill gas will displace petroleum-derived fuels and reduce the natural gas used to make them. Diesel fuel sold in California during November 2010 totaled 207 million gallons. California's biomethane resources (estimated at 125 bcf/yr) could displace that and more, over 670 million gallons of diesel if fully utilized.	This demonstration project will produce 13,000 gal. of LNG/day, displacing 2.8 million gallons of diesel fuel/yr while trapping of high global warming potential landfill gas. This fuel will have production costs but its price will not include the scarcity premiums expected with petroleum products and it will not have petroleum's environmental costs.
Description 7	Purification and Liquefaction of Biomethane Landfill Gas for Transportation Fuel	Over 40% of the natural gas consumed in the industrial sector is used to refine petroleum into diesel fuel.	This project will produce 13,000 gal. of LNG/day, displacing 2.8 million gallons of diesel fuel/yr. Saving 2.8 million gallons of diesel fuel/yr will save 127 thousand therms of natural gas/yr used in refining petroleum to obtain that diesel fuel.
Description 8	California Transportation Fuels Crops Development and Demonstration Program	Petroleum production sequesters geologically trapped carbon, therefore it would benefit California to figure out which crops can be cost effectively grown for fuel. California on road vehicles emitted over 153 million metric tons of CO2 equivalent in 2008. Each gallon of gas avoided saves about 8.8 kg of CO2 equivalent emissions.	We are investigating the suitability of certain fuel crops for CA. If grown, they would displace gasoline and diesel, to some degree, and reduce GHG emissions. These fuels are potentially sustainable. The State Alternative Fuels Plan established a moderate-case goal of 5 billion gallons of gasoline equivalent (gge) in alternative fuels market penetration by 2022. Successful research will advance the plan.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 9	California Transportation Fuels Crops Development and Demonstration Program	Petroleum production desquesters geologically trapped carbon, therefore it would benefit California to figure out which crops can be cost effectively grown for fuel. California on road vehicles emitted over 153 million metric tons of CO2 equivalent in 2008. Each gallon of gas avoided saves about 8.8 kg of CO2 equivalent emissions.	We are investigating the suitability of certain fuels crops for agriculture in CA. If grown, they would displace gasoline and diesel, to some degree, and reduce GHG emissions. These fuels are potentially sustainable. Every drop of petroleum produced desquesters geologically trapped carbon. The State Alternative Fuels Plan established a moderate-case goal of 5 billion gallons of gasoline equivalent (gge) in alternative fuels market penetration by 2022. This amount of petroleum displacement would result in yearly savings of over 227 million therms worth of natural gas otherwise needed to refine petroleum into gasoline and diesel fuel. In addition, 5 billion gallons of gasoline when burned release 44 million tonnes CO2e. Each gallon of gas avoided saves about 8.8 kg of CO2 equivalent emissions.
Description 10	Hydrogasification Research and Demonstration: turning biomass into renewable natural gas and biofuels	We need to develop viable alternatives to conventional petroleum based transportation fuels, because conventional gasoline, diesel, and jet fuels are not sustainable. The State Alternative Fuels Plan established a moderate-case goal of 5 billion gallons of gasoline equivalent (gge) in alternative fuels market penetration by 2022. Thermochemical processes are one promising class of technologies for pursuing this goal.	These fuels are sustainable. Every drop of petroleum produced desquesters geologically trapped carbon. Each gallon of gas or diesel requires 0.044 therms of natural gas in refining. Instead this project will create a natural gas substitute, sustainable clean biomethane, and biogas fuels.
Description 11	Life Cycle Greenhouse Gas and Energy Analyses of Production of Algae Biofuels	Algae biofuels directly address the Energy Commission's Public Interest Energy Research Transportation Research Area objective of increasing alternative fuel use in California through sources that both reduce oil dependency and reduce the effects of climate change. While algae fuels will minimize land use impacts, a high-profile study recently argued that current methods of algae production could make algae fuels more carbon-intensive than conventional biofuels. Critics of this study argue that alternative algae processes and energy recovery from waste streams could more than compensate for these inputs. In particular, the efficient use of residual algae biomass and efficient harvesting techniques must be incorporated effectively into the overall process to improve sustainability. The uncertainty looming over the sustainability of algae biofuels suggests that the life-cycle performance of these fuels is a critical knowledge gap.	The objective of this project was to provide a better understanding of the energy and environmental implications of algae biofuels. The research evaluated existing life cycle assessment studies and compared them with a range of new analyses on algae production scenarios and process assumptions that had not been considered previously. California is a world leader in renewable fuels research and development, particularly algae fuels. This project supported a nascent California industry's development.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 12	Algae OMEGA (Offshore Membrane Enclosures for Growing Algae): growing oil-producing algae offshore in semipermeable enclosures	Algae biofuels address the objective of increasing alternative fuel use in California through sources that both reduce oil dependency and reduce climate change. This research develops and tests a novel method to grow algae in offshore enclosures offshore and fertilizing it with treated municipal sewage.	Phototrophic algae is a fast growing organism good at absorbing CO2 and producing oils quickly. OMEGA is a game changer because it is a completely new way to cultivate phototrophic algae. Before OMEGA, there were only two ways: closed photobioreactor and open pond. OMEGA is a third way, increasing the chance that algal biofuels will become commercially competitive. In addition using wastewater to grow algae would provide secondary sewage treatment while creating biomass in a way that does not compete with food production for land and water.
Description 13	Production of Soladiesel RD™ Cellulosic Feedstock: making alternative diesel fuel from biomass through heterotrophic algal fermentation	Developing a viable process for algal fermentation of cellulosic biomass into alternative fuels that could replace fossil fuels would enhance national security, avoid future high costs of a depleting fossil fuel resource, and substantially reduce carbon emissions. Algae can be a fast growing and rich source of biofuels, but is typically cultivated photosynthetically, not fed heterotrophically as in a fermentation process.	Solazyme is a game changer because it uses algal fermentation in the dark and hence in big tanks including converted ethanol tanks. Most other algal processes require photosynthesis. Solazyme succeeded in demonstrating proof of concept in three principal areas including engineering their lead fuels strain to metabolize xylose sugars, evolving their lead fuels strain to grow more robustly and produce oil from cellulosic feedstocks, and converting cellulosic sugars into oil and diesel. `
Description 14	Production of Soladiesel RD™ Cellulosic Feedstock: making alternative diesel fuel from biomass through heterotrophic algal fermentation	Cellulosic biomass has a very low life cycle carbon footprint.	If Solazyme successfully commissions one commercial facility a year between 2017 and 2020, they could produce an estimated 400 million gallons of Soladiesel, potentially replacing up to 10% of California's current diesel consumption and reduce greenhouse gas emissions by 4.1 million tonnes.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 15	On-Site Aerobic Fermentation of California Cellulosic Agricultural Waste into Biofuel: creating alternative fuels through a bacterial pathway	Developing a viable process for bacterial fermentation of cellulosic biomass into fuels that could replace fossil fuels would enhance national security, avoid future high costs of a depleting fossil fuel resource, and substantially reduce carbon emissions.	<p>The contractor succeeded in converting lignocellulosic wastes into fuels in the laboratory, with a procedure he projects will cost \$2 per gallon when produced on an industrial scale. This would be a game changer, supplanting large amounts of diesel fuel consumption. The positive test results greatly enhance the contractor's chances of finding follow-on funding to bring the product to market.</p> <p>The product has large production potential given the 17 million bone tons per year (MBDT/yr) of lignocellulosic waste in California's agricultural and municipal waste streams and 14.2 MBDT/yr of forest waste (per 2009 Bioenergy Action Plan). Although the Menon process was applied to almond husk and grape pomace in this project, it is indeed suitable to virtually all of California's lignocellulosic biomass.</p>
Description 16	Improved Greenhouse Gases Inventory Methods for California Landfills	Per AB 32, starting in 2012, energy utilities have to comply with ARB's cap-and-trade program. Landfills offer potential offsets for utilities that would enable them to lower their compliance costs. However, the methods being used to estimate emissions are very uncertain and, for this reason, ARB is not allowing the use of offsets from landfills at this time. In 2006, landfill methane emissions were estimated at 6.3 million metric tonnes CO2 Eq. (which is about 10 percent of what is emitted from in-state power plants). The implementation of the ARB Scoping Plan using mandatory measures would reduce direct emissions by 1 million metric tonnes CO2 Eq., so in theory landfills could be an important source of offsets. Other mandatory control measures are being developed by ARB.	AB32, the California Global Warming Solutions Act, was adopted when this project was envisioned in 2005 but PIER anticipated regulatory activities allowing the use of offsets/allowances which became a reality with AB32. If this research makes estimation of landfill emission avoidance accurate enough to use as carbon offsets, ratepayers will save considerable, but as yet unquantified, amounts of money in lower electricity prices. The implementation of the ARB Scoping Plan using mandatory measures would reduce direct emissions by 1 Mt CO2 Eq.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 17	Climate Change and Sea Level Rise: Implications for the California Coast	<p>California's long coastline is home to many thermoelectric power plants, which are vulnerable to sea level rise and the ensuing increased flooding and inundation risk that would result in disruption of energy generation and supply. Thirty coastal power plants are potentially at risk, with a combined capacity of more than 10,000 megawatts (MW) (about 16 percent of in-state capacity), from a 100-year flood with a 1.4 m sea-level rise. source: http://www.pacinst.org/reports/sea_level_rise/exec_sum.pdf</p>	<p>Scientifically robust estimation of sea level rise and coastal evolution will contribute towards sound adaptation strategies mitigating/protecting the coastal power plants from the impacts of climate change and in turn, California's ratepayers and economy. With preventive measures the ratepayers will avoid major disruptions in their lifestyles and costly rate hikes from reconstruction after a coastal flood.</p> <p>\$130 billion/year of property is at risk of coastal flooding because of climate change, and can be protected for \$20 billion with seawalls, levees, and assorted maintenance suggested by PIER funded studies. The California State Park system owns 1/3 of coastal real estate and consults PIER-funded studies in its coastal park planning process. Private land development is regulated by the California Coastal Commission (CCC) and the Bay Conservation Development Commission (BCDC). CCC references PIER-funded and co-funded studies "all the time" to make sure development projects will be prepared for flooding, erosion, storm events, and high waves due to climate change. BCDC used PIER-funded research to develop protocols that communities must use to ensure future development will be protected from sea level rise. One BCDC application: The Hunter's Point redevelopment project in San Francisco will be worth \$8.7 billion but would be too close to the sea for development without climate protection guidance. It can now build with a \$2 billion grading investment plus much cheaper actions based on the BCDC protocols.</p>

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 18	Estimation of Long-Term Energy-Efficiency Potentials for California Buildings and Industry	<p>To comply with AB32's emission target and the 2050 GHG emission reduction goal, utilities have to reduce GHG emissions by unprecedented amounts. Improving energy efficiency is one of the major elements towards the 2020 target and the 2050 goal, but no long-term assessments for the potential of energy efficiency existed prior to this project.</p> <p>It is projected that the GHG emission levels will be approximately 600 MMTCO₂e in the year 2020. http://www.arb.ca.gov/cc/inventory/pubs/reports/staff_report_1990_level.pdf</p>	This study was one of the first (if not the first) studies to assess the challenges and opportunities associated with meeting the state's 2050 GHG emissions reduction target. It was found that for residential, commercial, and industrial sectors, natural gas demand could be reduced by around 34%, and electricity demand could be reduced by around 36% by 2050 at reasonable costs.
Description 19	Observation of Methane and other Non-Carbon Dioxide Greenhouse Gas Emissions from California	<p>Per AB 32, starting in 2012 energy utilities have to comply with ARB's cap-and-trade program. However, there are substantial uncertainties in estimated emissions. GHG emissions from electric utilities are relatively well known but this is not the case for other sources including the natural gas system. Incorrect emissions estimates may ultimately increase the cost of the cap-and-trade program for electric utilities. Better emission estimates will also improve the technical and environmental integrity of the cap-and-trade program. (Source: Energy Commission's Energy Consumption Data Management System) Note: Used an emission factor for natural gas of 11.7 lbs CO₂/Therm.</p>	Better emissions estimates early in the regulatory process affecting the 2020 target and 2050 goal would reduce regulatory uncertainty for utilities and will enable utilities to better manage their operation under the cap-and-trade program, passing the savings to ratepayers.
Description 20	Validation of a New Technology for Real-Time Measurement of the Isotopic Composition of Methane in Ambient Air	<p>Per AB 32, starting in 2012 energy utilities have to comply with ARB's cap-and-trade program. However, considerable uncertainties exist in the estimation of methane emissions from almost all the sources including the natural gas system. It was believed that measuring the isotopic signatures in atmospheric methane could detect problems with specific sources' emission estimates or uncover unexpected sources of emissions.</p> <p>Underestimated emissions from the natural gas system and other sources could require additional emission reductions from the energy utilities which would affect electricity rates. Overestimated emissions may result in costly and ineffective mitigation programs. (Source: Energy Commission's Energy Consumption Data Management System) Note: Used an emission factor for natural gas of 11.7 lbs CO₂/Therm.</p>	Better emissions estimates will enable utilities to meet GHG emissions reduction mandates and better manage their resources under the cap-and-trade program, passing the savings to ratepayers. The benefits of this project are qualitative.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 21	California AUAV Air Pollution Profiling Study: climate change impacts and adaptation	Hydropower provides about 15% of the in-state generation. Hydropower is a key peak hour supply source during the high demand summer months and is needed to help stabilize the grid. Among the many varieties of aerosols, black carbon may induce early melting of snow, reducing hydropower generation capacity in the hot summer months. About 75 percent of hydropower units in California rely on the snowpack as a natural water reservoir. An early melting of snow reduces the reservoir capacity of the snowpack.	Early melting of snow results in less hydropower in summer, when price is higher. Better understanding on the role of black carbon on snowpack contributes to better planning and management of summer energy supply. With better planning, utilities and ratepayers will avoid paying the high peak market price for electricity. With respect to the inherent uncertainties of this research, the value and benefits are qualitative such as increased knowledge and information and informed public policy.
Description 22	Estimation of Methane Emissions from the California Natural Gas System: GHG Inventory Methods	The ARB Scoping Plan requires natural gas utilities to reduce fugitive methane emissions from the natural gas systems. Total fugitive emissions from natural gas transmission are estimated to be 1.7 MMTCO ₂ E in 2020. The proposed control measure is expected to reduce fugitive methane emissions by approximately 0.9 MMTCO ₂ E per year. ARB is developing regulations to control these emissions but the emission estimates are highly uncertain, jeopardizing the fairness of the regulations. Without accurate information on actual fugitive methane emissions, improper and costly control measures could be imposed on natural gas utilities.	This project developed technically and environmentally sound control measures that would lower compliance costs and reduce energy prices to consumers. After field testing at 25 natural gas facilities, researchers found that at the component level, the actual leak rates are typically a few times higher than the prevailing rates. ARB will use the findings of this project to generate a California-specific emissions inventory and regulations. The value and benefits of this research are qualitative and include increased knowledge, environmental quality, information and informed public policy.
Description 23	Improving Regional Climate Models: Aircraft Collection of Data	Some studies suggest that aerosols emitted in California are reducing precipitation levels in the Sierra Nevada by about 12%, which represents substantial loss of low cost and clean electricity. These reductions imply less hydropower generation which is an important source of electricity in California. Natural gas is the fuel of choice for the electricity sector in California, and emits pollution particles.	More water available during summer peak hours facilitates lower electricity rates. The maximum potential increase of hydropower generation is about 12%, but substantial uncertainties remain in this estimation and in the relationship between aerosols and precipitation. Qualitative Benefits: More information on the effects of aerosols and precipitation levels will guide knowledge of expected water levels for hydropower consumption and allow more informed management of hydropower electricity generation.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 24	The potential of biochar soil amendments as a carbon sequestration method in California agriculture	<p>In order to increase energy efficiency in the agricultural sector, innovative sources of renewable energy must be found. One such strategy is the production of biochar through the pyrolysis of agricultural waste products. Waste products, such as biochar, may also have beneficial uses as soil amendments which can potentially promote carbon sequestration in the soil, thereby offsetting emissions from energy producers. There currently have been no assessments on the potential reductions of GHG emissions from California soils amended with biochar. If biochar soil amendments are practically and economically feasible, it will present a potential energy source (biochar production) and offset for energy producers in California. (Source: Energy Commission's Energy Consumption Data Management System)</p>	<p>Recent research has shown that biochar has the potential to remain as a stable form of carbon in the soil from centuries to millennia, thereby showing great potential as a carbon offset for energy producers in future cap and trade markets.</p> <p>By providing a source of energy production and use as a GHG mitigation and offset method, the production and use of biochar could help energy producers meet future emission caps and keep the cost of energy low for future rate payers.</p> <p>Qualitative Benefits: With respect to the inherent uncertainties of this research, the value and benefits of this research are increased knowledge and information and informed public policy.</p>
Description 25	Laboratory Validation of Novel Greenhouse Gas Monitoring Techniques	<p>Per AB 32, energy utilities have to comply with ARB's cap-and-trade program. Considerable uncertainties exist in the estimation of methane emissions from almost all the sources, including the natural gas system. It was believed that measuring the isotopic signatures in atmospheric methane could detect problems with specific sources' emissions estimates or uncover unexpected source of emissions. This was a companion study to contract 500-06-019 (Validation of a New Technology for Real-Time Measurement of the Isotopic Composition of Methane in Ambient Air) under which a novel instrument was used to measure the isotopic composition of atmospheric methane. This study was a third party validation of the measurements taken with the novel instrument during field measurements in California.</p> <p>Underestimated emissions in the natural gas system from non-utility sources could require additional emission reductions from the energy utilities which would affect energy rates.</p>	<p>Better emissions estimates will enable utilities to meet GHG emission reduction mandates and better manage their resources under the cap-and-trade program, passing the savings to ratepayers. The benefits of this project are qualitative.</p>

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 26	Adaptation Strategies for Agricultural Sustainability in Yolo County, California	Sustainable agriculture can reduce energy consumption, mitigate GHG emissions and promote carbon sequestration. Mitigation and carbon sequestration strategies also provide potential carbon offsets for energy producers in future cap and trade markets. This project is investigating how strategies for mitigation and adaptation can increase agricultural sustainability, incorporate a range of ecosystem services, and ensure resilience to the uncertainties of climate change. (Source: Energy Commission's Energy Consumption Data Management System)	Results not reported.
Description 27	Certification and Field Demonstration of a 0.2 g/bhp-hr NOx HPDI LNG Truck: Westport 15L GX Heavy-Duty LNG engine equipped with High Pressure Direct Injection (HPDI)	Exposure to ozone and other photochemical oxidants has been associated with a wide range of human health effects in general populations, including the aggravation of heart and lung disease, and premature mortality. The ARB and the U.S. EPA have adopted an oxides of nitrogen (NOx) emission standard of 0.20 g/bhp-hr for heavy-duty engines beginning in 2010. Heavy-duty Natural Gas Otto-cycle engines currently exist that can meet the 2010 NOx standards, but they experience efficiency disadvantages compared to diesel engines.	Research test results demonstrated that the Westport GX engine achieved less than the 0.20 g/bhp-hr NOx emission levels while maintaining diesel like performance. Certification for ARB and EPA 2010 was satisfactorily met in June of 2010. The Westport GX engine extends the vehicle capability to heavier vehicles (80,000 lb. GVW trucks) and avoids the fuel efficiency disadvantages of Otto-cycle engines due to throttling, spark-ignition, and low compression. Sixty percent of the Class 8 vehicle population is represented by the 15L engine size range. The Westport GX engine could replace 33% of these engines by 2020 and in applications such as drayage, refuse, and freight delivery. This would equal 257,000,000 gallons of diesel displaced per year.
Description 28	Certification and Field Demonstration of a 0.2 g/bhp-hr NOx HPDI LNG Truck: Westport 15L GX Heavy-Duty LNG engine equipped with High Pressure Direct Injection (HPDI)	Exposure to ozone and other photochemical oxidants has been associated with a wide range of human health effects in general populations, including the aggravation of heart and lung disease, and premature mortality. The ARB and the U.S. EPA have adopted an oxides of nitrogen (NOx) emission standard of 0.20 g/bhp-hr for heavy-duty engines beginning in 2010. Heavy-duty Natural Gas Otto-cycle engines currently exist that can meet the 2010 NOx standards, but they experience efficiency disadvantages compared to diesel engines.	For class 8 vehicles, 99.6% of the fuel use is diesel. Each gallon of diesel replaced by natural gas in heavy duty trucks saves 2.15 kg of CO2 equivalent emissions. Extra costs of \$80,000 as well as \$50,000 in federal and state incentives per vehicle would be required to achieve 95% of fuel displacement. Sixty percent of the Class 8 vehicle population is represented by the 15L engine size range. The Westport GX engine could replace 33% of these engines by 2020 in applications such as drayage, refuse, and freight delivery.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 29	Natural Gas Vehicle Research: engine technology, vehicle technology, and infrastructure	In order to expand the use of natural gas as a transportation fuel, vehicle availability must improve. There remain technical barriers associated with emissions, efficiency, performance, and cost that will require research and development to expand the natural gas vehicle market. Having additional vehicle choices will be important in order to achieve the petroleum reduction and GHG reduction potential of natural gas.	The research developed in this study will identify the highest value current and future RD&D efforts required to build a sustainable natural gas vehicle market within California. Consolidating private and public stakeholder guidance on the implementation of natural gas vehicle RD&D will lead to a better prioritization of projects, which will develop and help bring to market advanced transportation technologies that reduce air pollution and GHG emissions. The benefits related to this project are qualitative.
Description 30	Ultra-Low Emissions, 12-13 Liter Heavy Duty Natural Gas Engine Development	The Air Resources Board's 2006 study, Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, states that diesel fumes from the ports of Los Angeles and Long Beach are elevating the risk of cancer, and are especially unhealthy for children and the elderly, not only adjacent to the ports but over the entire 400 square-mile study area. Natural gas is a "clean" alternative to diesel. However, natural gas engines have a higher cost than their diesel counterparts and have performance and efficiency disadvantages. Diesel-like performance and efficiency levels for natural gas engines are needed to drive volume in the heavy-duty market sector.	In comparison with diesel-fueled Class 8 trucks, the 11.9 L Natural Gas powered Class 8 trucks are projected to deliver full fuel cycle GHG advantages ranging from 10% to 44%, depending on the engine's fuel economy relative to diesel engines and the proportion of renewable and conventional natural gas fuel sources in the future in California. The SESI technology is capable of criteria pollutant emissions that are lower than the U.S. EPA / ARB 2010 on-highway emission standards (g/bhp-hr): 0.20 NOx, 0.14 NMHC, 0.01 PM, 15.5 CO. Twenty five percent of California's Class 8 vehicle population is focused on regional haul, which is the intended use of this engine. By 2020 one might expect a 30% market penetration driven by cost benefits of the engine technology and fuel price differential. A smaller 10% market penetration would equal 97,500,000 gallons of diesel displaced per year.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 31	Ultra-Low Emissions, 12-13 Liter Heavy Duty Natural Gas Engine Development	<p>The Air Resources Board's 2006 study, Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, states that diesel fumes from the ports of Los Angeles and Long Beach are elevating the risk of cancer, and are especially unhealthy for children and the elderly, not only adjacent to the ports but over the entire 400 square-mile study area. Natural gas is a "clean" alternative to diesel. However, natural gas engines have a higher cost than their diesel counterparts and have performance and efficiency disadvantages. Diesel-like performance and efficiency levels for natural gas engines are needed to drive volume in the heavy-duty market sector.</p>	<p>The 11.9 L Natural Gas powered Class 8 trucks, in comparison with diesel-fueled Class 8 trucks, are projected to deliver full fuel cycle GHG advantages ranging from 10% to 44%, depending on the proportion of renewable and conventional natural gas fuel sources in the future California transportation natural gas fuel supply and also depending on the 11.9 L NG engine fuel economy relative to diesel engines at launch. The SESI technology is capable of criteria pollutant emissions that are lower than the U.S. EPA / ARB 2010 on-highway emission standards (g/bhp-hr): 0.20 NOx, 0.14 NMHC, 0.01 PM, 15.5 CO. Twenty five percent of the Class 8 vehicle population is focused on regional haul. The Cummins Westport 11.9 L NG engine fits this vocation. By 2020 one could expect a 30 percent market penetration driven by cost benefits of the engine technology and fuel price differential. A smaller 10% market penetration is used to be more conservative. 97,500,000 gallons of diesel displaced per year based on 10% market penetration.</p>
Description 32	Lower Cost High Performance and High Efficiency Pilot-Ignited Directly Injected HD Natural Gas Engine	<p>Natural gas vehicles are a clean alternative to using diesel fueled vehicles, but they are challenged by the cost of the natural gas engines needed to deliver engine performance equal to diesel engines. Cost reductions are needed, and critical, to the success of enabling the growth of natural gas vehicles.</p> <p>This research will reduce the initial ownership and operating costs of High Pressure Direct Injection technology and explore efficiency improvements. Recognizing that gas quality may be more variable as a result of new sources of natural gas entering the market, the research also proposes to explore options for reducing sensitivity to fuel composition variance using a novel sensor technique recently developed under Department of Energy sponsorship.</p>	<p>The goals of this research are to reduce the Heavy-Duty High Pressure Direct Injection (HPDI) engine system component costs by 20%, reduce HPDI fuel consumption by 5% and improve HPDI power density by 10%, while maintaining emissions below ARB 2010 emission targets and reducing GHGs by 20%. These additional performance and cost benefits are expected to drive market penetration in Class 8 vehicles by an additional 10%. (previous Westport GX Engine was estimating 33%) Ultimately, this research could lead to 25,700,000 gallons of diesel fuel displaced per year based on a 33% market penetration.</p>

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 33	Lower Cost High Performance and High Efficiency Pilot-Ignited Directly Injected HD Natural Gas Engine	<p>Natural gas vehicles are a clean alternative to using diesel fueled vehicles, but they are challenged by the cost of the natural gas engines needed to deliver engine performance equal to diesel engines. Cost reductions are needed, and critical, to the success of enabling the growth of natural gas vehicles.</p> <p>This research will reduce the initial ownership and operating costs of High Pressure Direct Injection technology and explore efficiency improvements. Recognizing that gas quality may be more variable as a result of new sources of natural gas entering the market, the research also proposes to explore options for reducing sensitivity to fuel composition variance using a novel sensor technique recently developed under Department of Energy sponsorship.</p>	The goal of this research is to increase the use of natural gas in the place of diesel fuel using the Heavy-Duty High Pressure Direct Injection (HPDI) engine system. For class 8 vehicles, 99.6% of the fuel use is diesel; each gallon of diesel avoided saves 10.1 kg of CO2 equivalent emissions. Calculations from members of PIERs Transportation group verify that the CO2 equivalent emissions from natural gas, when compared to a gallon of diesel fuel are 21% lower. Therefore, the 260,000 Tonnes of CO2e saved by this engine from diesel fuel not used are balanced with the equivalent amount of natural gas used, which equals 205,400 Tonnes of CO2e. The difference between the two emissions totals is the savings: 260,000 - 205,400 = 54,600 Tonnes of CO2e (or 21% of 260,000).
Description 34	Gas Optimized Advanced Heavy Duty Engine Concept: Development of a 13L Natural Gas Engine concept with High Pressure Direct Injection Technology	The overall objective of this research is to develop a natural gas engine concept with diesel engine drivability and efficiency. A large displacement natural gas engine has difficulty achieving diesel power and efficiency due to the combustion process and throttle operation at part-load. Research is needed to overcome barriers to increased engine displacement size while low emission levels and high efficiency are maintained. The research will also investigate the potential to further improve fuel efficiency through enhanced in-cylinder mixing. The intended outcome of the research is to reduce the diesel requirements of the engine by 90% and to lower GHG emissions by 20% while complying with California's emission regulations, and keeping non-regulated emissions at sustainable levels.	This project will contribute to increased adoption of high-efficiency, heavy-duty natural gas vehicles in the California market, and more broadly, in North American markets, by improving the emission performance of natural gas engines to meet the ARB/US EPA 2010 emission standards. Twenty five percent of the Class 8 vehicle population is focused on regional haul which is an intended use of the Volvo 13 L NG engine. The expected 10% market penetration of this engine will result in 97,500,000 gallons of diesel displaced per year.
Description 35	Gas Optimized Advanced Heavy Duty Engine Concept: Development of a 13L Natural Gas Engine concept with High Pressure Direct Injection Technology	The overall objective of this research is to develop a natural gas engine concept with diesel engine drivability and efficiency. A large displacement natural gas engine has difficulty achieving diesel power and efficiency due to the combustion process and throttle operation at part-load. Research is needed to overcome barriers to increased engine displacement size while low emission levels and high efficiency are maintained. The research will also investigate the potential to further improve fuel efficiency through enhanced in-cylinder mixing. The intended outcome of the research is to reduce the diesel requirements of the engine by 90% and to lower GHG emissions by 20% while complying with California's emission regulations, and keeping non-regulated emissions at sustainable levels.	Natural Gas Engines reduce GHG emissions by 21% over diesel engines. For class 8 vehicles, 99.6% of the fuel use is diesel; each gallon of diesel avoided saves 10.1 kg of CO2 equivalent emissions minus the emissions from the equivalent amount on natural gas.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 36	Improving Efficiency of Spark Ignited, Stoichiometrically-operated Natural Gas Engines: application of mobile technology to stationary natural gas engine applications with specific implementation of variable engine valve actuation	In response to California's goal of installing up to 4000 MW of new distributed generation capacity over the next decade this research will focus on using reciprocating piston internal combustion engines that respond to fluctuating loads from sources like wind and solar generation by turning on and off in order to match supply and demand. In this manner peak efficiencies can be achieved nearly all of the time, avoiding the poor efficiencies associated with part load operation. Distributed Power Systems like this can be implemented on small as well as large scales; large scale installations make use of a plurality of engines.	This project aims to demonstrate breakthrough natural gas engine efficiencies, while meeting California emission standards for distributed resources without the use of lean NOx after-treatment. The high level goals of the program include: • Brake Thermal Efficiency of 40%, translating into an average efficiency improvement of up to 20% over current technology • NOx emissions levels of <0.032 g/kw-hr (0.064 g/kw-hr) in CHP systems • Elimination of lean NOx after-treatment system translating in up to \$30,000 savings per engine (assuming 1MW power rating per engine) • Seamless adaptation to varying fuel quality using closed-loop combustion control. At full penetration, efficiency gains would result in a reduction in fuel consumption of 6.9 million Mcf (71 million therms) per year. If CHP systems are enabled by the distributed power approach, the reduction in fuel consumption increases dramatically to 31 million Mcf (320 million therms) per year. In addition, the elimination of lean NOx after-treatment is estimated to save \$40,000 per engine, translating into \$48M in the implementation of 30% of the 4000 MW of power. Closed-loop combustion control will allow for the efficient use of many more NG supplies including low quality or low energy content gas.
Description 37	Advanced Radiant Heating, Ventilation, and Air Conditioning Systems for California Homes	This research aims to reduce system costs and improve energy efficiency for HVAC systems in existing and new buildings.	The estimated annual electricity savings in 2025 range from 1,158 GWh to 1,382 GWh.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 38	Advanced Radiant Heating, Ventilation, and Air Conditioning Systems for California Homes	This research aims to reduce system costs and improve energy efficiency for HVAC systems in existing and new buildings.	The estimated annual natural gas savings range from 46 million to 142 million therms.
Description 39	Advanced Radiant Heating, Ventilation, and Air Conditioning Systems for California Homes	This research aims to reduce system costs and improve energy efficiency for HVAC systems in existing and new buildings.	The peak demand reduction addressed in this research ranges from 907 MW to 1,248 MW.
Description 40	Improved Natural-Gas Fired Aluminum Smelting Burner	Secondary aluminum melting has a low thermodynamic efficiency of approximately 25% and is carried out most commonly in reverberatory furnaces fired with air and natural gas. This research aims to develop new technology that will reduce the emission of pollutants (Nox and CO) without an efficiency penalty.	Previous designs emitted 0.33 lbs of NOx and 0.36 lbs of CO per ton of aluminum alloy produced. This new design emits 0.2 lbs of NOx and 0.2 lbs of CO per ton of aluminum alloy produced, resulting in approximately 1.22% improvement in overall energy efficiency, and a potential savings of 147,000 therms annually.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 41	Field Demonstration of Prototype Natural Gas Fired Super Boiler, demonstrated in a Food Processing Use	Current fire-tube Natural Gas boiler designs are typically 80% to 84% efficient. A new gas-fired steam generation system is needed for increased energy efficiency, reduced equipment size, and reduced emissions. DOE funded the initial research but high cost game-change products like this, which require high company investment, generally can't be commercialized without a demonstration.	The new fire-tube Natural Gas boiler design is 92% to 94% energy efficient compared to older designs with efficiency ranges of 80% to 84%.
Description 42	Field Demonstration of Prototype Natural Gas Fired Super Boiler, demonstrated in a Food Processing Use	Current fire-tube Natural Gas boiler designs are typically 80% to 84% efficient. A new gas-fired steam generation system is needed for increased energy efficiency, reduced equipment size, and reduced emissions. DOE funded the initial research but high cost game-change products like this, which require high company investment, generally can't be commercialized without a demonstration.	This row shows projections of benefits with market penetration at 5% of what DOE estimated, reduced in order to be conservative given CEC commercial survey indications.
Description 43	Design and Development of Low-Cost, High-Temperature, Non-tracking Solar Collectors for food processing, and mass production	Significant increases in the price of natural gas and increasingly stringent emission requirements have prompted inquiries by industrial gas users for alternative sources, including solar technologies, for process heat needs. This project demonstrated the cost-effectiveness of high-temperature solar collectors for the production of heat for industrial processes. Solar collectors that track the Sun are complex, have moving parts that can break, and have extra expense. Simplifying solar collector design can reduce the price of steam generation solar collectors to cost competitive levels. (Source: Energy Commission's Energy Consumption Data Management System)	This new design provides 90% of the heating efficiency of previous tracking designs at an estimated \$15 to \$18 per square foot, making cost competitive solar replacement of natural gas hot water and steam generation a real possibility. The current state of art costs approximately \$30 per square foot. The estimated benefits assume a 5% market penetration.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 44	Reduce Natural Gas Use for Industrial Process Heat using High-Temperature Parabolic Trough Solar Collectors: proof of concept solar thermal steam generation augmenting natural gas fired boiler	This project demonstrated the feasibility of adding solar thermal energy to an existing manufacturing facility. Solar augmentation of natural gas fired boilers is an underutilized possibility in California's Central Valley where facilities have ample sunshine and land. (Source: Energy Commission's Energy Consumption Data Management System)	This project provided a proof of concept in a major facility. The system design provided for an adequate solar concentrator area, as well as steam and hot water generation equipment, which meets the goal of a 20% to 30% reduction in plant natural gas use during peak summer days. The final design, construction and startup cost of the project was \$3.95 million, or \$0.439 per BTU/hr (\$1500 per kWt) of thermal output. This cost allows for a payback period below 10 years depending on natural gas prices. This project yields both quantitative and qualitative benefits. The quantitative benefits are estimated to be 147,000 industrial therms for this demonstration project. Qualitative benefits include encourage the development of solar hot water heating to reduce the reliance on natural gas for water heating. It will also improve reliability and energy efficiency of electricity and natural gas and lower NOx emissions, improving air quality.
Description 45	Reverse Annulus Single Ended Radiant Tube (RASERT): Advanced indirect heat natural gas fired Radiant Heat Tube to replace state of the art Single Ended Radiant Tubes	The California Steel Industries (CSI), a steel galvanizer located in Fontana, California, San Bernardino County, California, collaborated with the Gas Technology Institute (GTI) and the Energy Commission PIER Program to develop a reverse-annulus (ring), single-ended radiant tube (RASERT) for industrial furnaces. Source: CEC-500-2009-062, "Deployment of the RASERT." The research objectives include developing the RASERT technology, integrating RASERT, and conducting a field trial of a highly efficient heat tube for use in industrial process heat treatment, i.e., furnaces. The field trial was conducted at CSI. California's heat treating industry currently uses gas-fired single-ended radiant tubes (SERTs) as one of four technologies to provide process heating in atmosphere controlled furnaces in the ferrous and non-ferrous metals industry. SERT technology typically has a heat transfer efficiency of only 50%.	Benefits realized from this demonstration, which included the installation of 12 RASERTS: Natural gas consumption reduced 25 percent, annually (estimated at 2 billion Btu annually; or .00001*2,000,000,000 therms/yr= 20,000 therms/yr), The section of the CSI steel galvanizing line retrofit with the RASERTS was available 90% of the time; the automatic control fired each RASERT at a 50 percent firing rate with the temperature held near 1575 °F. Each RASERT consumed approximately 70,000 Btu/hr of natural gas, and delivered approximately 65 percent of this energy to the furnace in the form of heat, thereby each RASERT supplied 45,500 Btu/hr of heat to the furnace. Without the RASERT burners, the natural gas consumption would have been 91,000 Btu/hr.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 46	Reverse Annulus Single Ended Radiant Tube (RASERT): Advanced indirect heat natural gas fired Radiant Heat Tube to replace state of the art Single Ended Radiant Tubes	The California Steel Industries (CSI), a steel galvanizer located in Fontana, California, San Bernardino County, California, collaborated with the Gas Technology Institute (GTI) and the Energy Commission PIER Program to develop a reverse-annulus (ring), single-ended radiant tube (RASERT) for industrial furnaces. Source: CEC-500-2009-062, "Deployment of the RASERT." The research objectives include developing the RASERT technology, integrating RASERT, and conducting a field trial of a highly efficient heat tube for use in industrial process heat treatment, i.e., furnaces. The field trial was conducted at CSI. California's heat treating industry currently uses gas-fired single-ended radiant tubes (SERTs) as one of four technologies to provide process heating in atmosphere controlled furnaces in the ferrous and non-ferrous metals industry. SERT technology typically has a heat transfer efficiency of only 50%.	NOx emissions were reduced by 55 percent (estimated at 492 pounds, annually), CO emissions were reduced by 58 percent (estimated at 243 pounds, annually), and CO2 emissions (carbon equivalent) were reduced by 25 percent (estimated at 232,000 pounds or 116 tons, annually). As detailed in the Final Report, the pollution emitted by the RASERTS depends on the steel product mix being processed at CSI, the temperature, the actual use of the production line, and other characteristics.
Description 47	Reverse Annulus Single Ended Radiant Tube (RASERT): Advanced indirect heat natural gas fired Radiant Heat Tube to replace state of the art Single Ended Radiant Tubes	The California Steel Industries (CSI), a steel galvanizer located in Fontana, California, San Bernardino County, California, collaborated with the Gas Technology Institute (GTI) and the Energy Commission PIER Program to develop a reverse-annulus (ring), single-ended radiant tube (RASERT) for industrial furnaces. Source: CEC-500-2009-062, "Deployment of the RASERT." The research objectives include developing the RASERT technology, integrating RASERT, and conducting a field trial of a highly efficient heat tube for use in industrial process heat treatment, i.e., furnaces. The field trial was conducted at CSI. California's heat treating industry currently uses gas-fired single-ended radiant tubes (SERTs) as one of four technologies to provide process heating in atmosphere controlled furnaces in the ferrous and non-ferrous metals industry. SERT technology typically has a heat transfer efficiency of only 50%.	The technical potential of RASERT is judged by GTI staff to be about half, or 2600, of the 5200 radiant tube assemblies in CA ("non-recuperated units similar to the burners examined during the baseline test"). The potential benefits of a market penetration of 2600 radiant tube assemblies in CA is therefore 2600 burners converted, saving 430,466,400 ft3/yr of natural gas (4.5 million therms), along with pollutant savings.
Description 48	Reverse Annulus Single Ended Radiant Tube (RASERT): Advanced indirect heat natural gas fired Radiant Heat Tube to replace state of the art Single Ended Radiant Tubes	The California Steel Industries (CSI), a steel galvanizer located in Fontana, California, San Bernardino County, California, collaborated with the Gas Technology Institute (GTI) and the Energy Commission PIER Program to develop a reverse-annulus (ring), single-ended radiant tube (RASERT) for industrial furnaces. Source: CEC-500-2009-062, "Deployment of the RASERT." The research objectives include developing the RASERT technology, integrating RASERT, and conducting a field trial of a highly efficient heat tube for use in industrial process heat treatment, i.e., furnaces. The field trial was conducted at CSI. California's heat treating industry currently uses gas-fired single-ended radiant tubes (SERTs) as one of four technologies to provide process heating in atmosphere controlled furnaces in the ferrous and non-ferrous metals industry. SERT technology typically has a heat transfer efficiency of only 50%.	At 100% penetration, NOx emissions would drop by 106,000 short tons, CO emissions would drop by 53,000 short tons, and CO2 emissions would drop by 25,000 short tons (23,000 metric tonnes), according to GTI estimates. As detailed in the Final Report, the pollution emitted by the RASERTS depends on the steel product mix being processed at CSI, the temperature, the actual use of the production line, and other characteristics.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 49	High Efficiency Gas-Fired Drum Dryer for Food Applications: to replace state of the art steam pressure vessel drum dryers	In California, dried and dehydrated fruit and vegetable processing consumes an estimated 6.2 Tbtu of energy, equivalent to 62 million therms of natural gas. Current steam drum dryers have low efficiencies of 60% to 70%, and can be highly dangerous due to possible steam explosions. Gas-Fired Drum Dryers could be safer with higher efficiencies.	The results show that gas-fired drum drying has a much higher efficiency, up to 85% to 90%. If all California dried and dehydrated fruit and vegetable processing operations switched from 65% to 87.5% efficiency, 14.6 million therms would be saved annually.
Description 50	Reducing Natural Gas Use in California Process Industries - Workshop and Roadmap Report	Road mapping is necessary to determine suitable research opportunities in California regarding natural gas technologies.	This is a roadmap for guidance on research. It will help plan the development of natural gas use in California, leading to increased reliability and energy efficiency for both electricity and natural gas.
Description 51	Develop recommendations to improve energy and water efficiencies in residential hot water heaters and hot water distribution systems	Residential water heating accounts for over 40% of all natural gas used in California homes and uses over 2 billion therms annually. This research addresses how to increase the energy efficiency of such systems.	Piping insulation rules developed, optimized, and incorporated in the standards for new construction will grow from saving around 2 million therms a year in 2010 to around 77 million therms a year by 2020, as new houses are built and an assumed 0.1% of the existing housing stock is retrofit each year. Net benefits in 2020 will be \$51 million a year: around \$74 million in avoided natural gas charges minus \$23 million in installation costs to consumers.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 52	Super efficient natural gas fired water heating appliance initiative	Residential water heating accounts for over 40% of all natural gas used in California homes and uses over 2 billion therms annually. This project will develop cost-effective replacement water heaters that have a 50% reduction in nitrogen oxide (NOx) emissions and an energy savings of approximately 30% compared to new conventional units.	A 1% increase in efficiency could save about 20 million therms annually and about \$11 million dollars per year.
Description 53	Hot Water Distribution System Research: Multi-family hot water distribution systems, hot water piping heat loss and improved showerhead performance with less water consumption	Multi-family buildings use approximately 150 million therms annually for hot water heating. Multi-family Hot Water Distribution Systems include advanced control systems for demand sensing, temperature modulation, and additional features such as remote monitoring, fault diagnosis and reporting. These systems may improve the long-term performance of multi-family hot water distribution systems but have not yet been adequately evaluated.	When implemented as a part of Title 24 Part 6, annual savings will be approximately 7.43 million therms from demand control as well as 1.17 million therms from pipe insulation.
Description 55	Water Heating and Hot Water Usage in California Homes: test alternative storage-type gas water heaters	Residential water heating is the second largest natural gas end use in California buildings using more than 2 billion therms per year. Therefore, end use efficiencies in residential water heating can yield huge natural gas savings.	1% sector savings

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 56	Unpressurized Solar Storage Tank for drain back systems	Residential water heating accounts for over 40% of all natural gas used in California homes and uses over 2 billion therms per year. Solar water heating could replace much of that.	40 tanks have been sold in the 9 months of commercialization to date, each saving about 150 therms per year, for perhaps 25 years. At this early stage, the cost of installing a solar water heating system is roughly comparable to the value of the system, so net dollar savings are zero. As solar water heating becomes standard rather than a retrofit costs will drop.
Description 57	Barriers to Expansion of Natural Gas Storage Facilities in California	There are insufficient natural gas storage facilities in California, and likely a variety of reasons that natural gas storage capacity has not been built despite FERC's revised rules that are intended to encourage new development. This project identified those barriers. (Source: 2007 Integrated Energy Policy Report)	This project conducted a comprehensive analysis of the barriers to natural gas storage with an emphasis on the market power threshold test by assessing how market power inhibited development of storage facilities in California. A better understanding of the barriers to the development of natural gas storage facilities may help policy makers improve the efficiency of natural gas markets, decreasing the price of natural gas and electricity to consumers (currently natural gas price drives electricity price because the marginal generation units use natural gas).
Description 58	Field Demonstration of 0.2 Grams Per Brake Horsepower-Hour NOx Natural Gas-Fired Engine that meets 2010 Nox emissions standards	Exposure to ozone and other photochemical oxidants has been associated with a wide range of human health effects. Heavy-duty vehicles alone are responsible for two thirds of NOx emissions in the U.S. The ARB and EPA have adopted a NOx emission standard of 0.20 g/bhp-hr for heavy duty engines to reduce levels of this critical ozone precursor.	Specific to heavy-duty commercial vehicles, the ARB and EPA reduced NOx standards from 1.2 g/bhp-hr in 2007 to 0.2 g/bhp-hr in 2010, a 6-fold reduction. Cummins Westport, Inc. sold more than 400 ISL G-powered vehicles incorporating this new engine design in 2009 and 2010, which displaced large amounts of diesel fuel. It is projected that the design will have a 25% market penetration rate in Class 6 and Class 7 vehicles, and a 5% market penetration in Class 8 vehicles, leading to even greater diesel fuel displacement.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 59	Field Demonstration of 0.2 Grams Per Brake Horsepower-Hour NOx Natural Gas-Fired Engine that meets 2010 Nox emissions standards	Exposure to ozone and other photochemical oxidants has been associated with a wide range of human health effects. Heavy-duty vehicles alone are responsible for two thirds of NOx emissions in the U.S. The ARB and EPA have adopted a NOx emission standard of 0.20 g/bhp-hr for heavy duty engines to reduce levels of this critical ozone precursor.	Specific to heavy-duty commercial vehicles, the ARB and EPA reduced NOx standards from 1.2 g/bhp-hr in 2007 to 0.2 g/bhp-hr in 2010, a 6-fold reduction. This new engine design displaced large amounts of diesel fuel while also reducing NOx emissions, and more NOx reductions are expected. See 500-06-043 (Task 2), Row 1 and 500-06-043 (Task 3) Row 1). It is projected that the design will have a 25% market penetration rate in Class 6 and Class 7 vehicles, and a 5% market penetration in Class 8 vehicles, leading to even greater diesel fuel and NOx emissions reductions. Each gallon of diesel avoided saves about 10.1 kg of CO2 equivalent emissions and natural gas use represents a 21% CO2e emissions reduction as compared to diesel.
Description 60	Using Gasoline, Diesel, and Compressed Natural Gas (CNG) Vehicles, Characterize the Significance of Lube Oil in PM Formation	<p>Particulate matter from vehicles may be the most significant single contributor to ambient fine particulate matter, which has been associated with a wide range of particulate matter-related human health effects, including the aggravation of heart and lung disease, and premature death.</p> <p>The U.S. Department of Energy's Gasoline/Diesel Particulate Matter Split Study concluded that particulate matter from spark-ignition vehicles contributes significantly to particulate matter emissions in the Southern California Basin. This area exceeds the federal particulate matter air quality standards of annual PM10 50 µg/m3 (micrograms per a cubic meter).</p> <p>The study aims to quantify the fraction of emissions derived from the combustion fuel and engine lubricating oil, and to determine the engine operating conditions that are responsible for the emissions.</p>	This research aims to provide the qualitative benefits of reduced air particulate matter and consequent improved air quality, which will lead to fewer health issues. The research will achieve this by determining the contribution of lubricant constituents to particulate emissions, as well as the effect of vehicles and fuels on the lubricant particulate emissions under various vehicle operating conditions, including changes in duty cycle and temperature.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 61	Using the California Fleet, Conduct Physicochemical and Toxicological Assessment of Particulate Matter Emissions	<p>Epidemiological and toxicological studies have demonstrated links between ambient particulate matter and adverse health outcomes ranging from cancer to cardiopulmonary disease.</p> <p>In urban environments, such as Los Angeles, the dominant source of ultrafine particulate matter is direct emissions from motor vehicles. This presents a barrier to alternative fuel vehicles, which have to compete with conventional vehicles on all fronts including emission control technologies.</p> <p>The research determines the relative toxicity of all particulate matter fractions from heavy- and light-duty vehicles operating with, and without, control technologies. The physical, chemical, and toxicological properties of emissions from these vehicles will be compared with emissions from other fuel types (diesel, biodiesel, gasoline, E-85).</p>	A well-functioning diesel trap can result in a particulate matter mass emission reduction of more than 95%. When a trap is integrated with selective catalytic reduction, nitrogen oxide emissions can also be reduced by more than 70%. Based on the reduction of diesel particulate matter mass, the relative cancer risk is correspondingly reduced by more than 90%. Qualitative Benefit: quality of life, decreased risk of illness, improved health
Description 62	Heavy-Duty Emissions and Fuel Consumption Improvement	Heavy-duty trucks are an important category to evaluate when looking for emissions reductions and fuel consumption savings in the transportation sector. In the U.S., diesel trucks emit approximately 7% of GHG emissions, 20% of ozone forming pollutants, and up to 50% of PM in urban areas. Among medium- and heavy-duty trucks, Class 8 trucks are the largest CO2 emitters and fuel users, consuming 2/3 of all truck fuel, which equals 1.57 million barrels per day.	Specific to heavy-duty commercial vehicles, the ARB and EPA reduced NOx standards from 1.2 g/bhp-hr in 2007 to 0.2 g/bhp-hr in 2010, a 6-fold reduction. Cummins Westport, Inc. sold more than 400 ISL G-powered vehicles incorporating this new engine design in 2009 and 2010, which displaced large amounts of diesel fuel. It is projected that the design will have a 5% market penetration in Class 8 vehicles, leading to even greater diesel fuel displacement.
Description 63	Determining the Volatility of Ultrafine Particulate Matter Emissions from Compressed Natural Gas Vehicles Control Technologies	<p>Emissions from motor vehicles in urban environments are the dominant source of ultrafine particulate matter that medical studies have linked to adverse health effects.</p> <p>The relative toxicity of emissions is the subject of on-going ARB research. However, while many studies have explored the volatility of diesel particulate matter, no studies have determined the volatility of ultrafine particulate matter emitted by CNG vehicles.</p> <p>This research characterizes the toxicity of non-volatile and semi-volatile fractions of ultrafine particulate matter emissions from CNG vehicles. For this project, new engines meeting stringent 2010 standards for PM and NOx will be tested.</p>	This research hopes to gain a better understanding of ultrafine particulate matter formation which will enable better control technologies. The qualitative benefits include improved quality of life, decreased risk of illness, and improved health.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 64	Energy and Water Recovery with Transport Membrane Condenser: The first non-boiler demonstration of Transport Membrane Condenser (TMC) technology	The food processing, paper drying, and chemical industries use process heat that generates low grade waste heat streams and consumes approximately 112 TBtu per year (1.12 billion therms) in California. This low grade energy is difficult to recover because 1) the relatively low temperature provides insufficient driving force for heat transfer; 2) water vapor condensation at lower temperature can cause equipment corrosion because of CO ₂ and/or SO ₂ content. Water vapor and its latent heat account for about 68% of the total heat lost up the stack in the applicable processes in these industries.	An analysis of industrial drying suggests that California can save 4.2 TBtu of natural gas per year, excluding recovery costs. There are also water savings and the operational benefit to some processes of having clean hot water available sooner after process startup.
Description 66	Waste Heat Recovery from Corrosive Industrial Exhaust Gases: Demonstration of gas cleaning technology to allow for heat recovery from high-temperature flue gas that contains corrosive elements	A number of industrial processes operate at low efficiencies because there are no commercial means available to recover heat economically from hot exhaust gases that contain corrosive elements such as chlorine and fluorine. Aluminum remelt furnaces in particular are excellent candidates for such a technology that deals with this issue as they typically operate at 30% efficiency with 60% of the input energy lost to the exhaust gas without recovery. This could save the approximately 2 TBtu of natural gas used to remelt aluminum in California annually.	Recuperation technology to recover exhaust gas heat would increase the overall aluminum remelt process efficiency from 30% to 40% and save more than 0.52 TBtu per year in California.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 67	<p>Natural Gas Variability in California:</p> <p>Environmental Impacts and Device Performance:</p> <p>Modeling and testing the impacts of variable natural gas supplies on end use performance, pollutant, and CO2 emissions. With the growing demand for natural gas in California, an alternative is to import LNG. A concern exists, however, about the increased use of LNG leading to pollution.</p>	<p>As new supplies of natural gas including LNG enter the California market, there is concern regarding the performance and efficiency of appliances and industrial burners. There also is concern over the likelihood of increasing undesirable emissions such as CO and NOx leading to poorer indoor and outdoor air quality when burning LNG with its higher heat content. (Source: Energy Commission's Energy Consumption Data Management System)</p> <p>This study addresses the use of natural gas in California covering the residential, commercial cooking, and industrial sectors. While these sectors represent only around 10% of all air-borne emissions, they correspond to consumption of more than half of all natural gas in California. For that reason, emissions from these units are critical to understanding when natural gas compositions are varied.</p>	<p>This research ensures that new natural gas supplies (imported LNG) can be used in California in a safe and environmentally sound manner while allowing for a wider range of gases.</p> <p>Other benefits will come from the use of data and modeling carried out in this project to improve indoor and outdoor air quality.</p> <p>Ratepayer savings from this study will come from California's acceptance of alternative natural gas supplies to supplement existing natural gas. Saving as little as \$0.20 per million Btu on as low an LNG import rate of 0.1 billion cubic feet per day will save California \$7.3 million per year. Actual savings could be much higher. The ability to use LNG in place of NG increases the supply of NG a maximum of 484 million cubic feet per day with current facilities. Research is being followed closely by air agencies & industry. ARB is using results in revising the Compressed NG Fuel Specifications for Motor Vehicles. As well as SDAPCD to prepare for the importation of LNG into their District. SCAQMD used results in their Final Staff Report for Proposed Rule 433 – Natural Gas Quality, May 2009.</p>
Description 68	<p>Gaseous Fuel Interchangeability Criteria</p> <p>Development: development and validation of design tools that describe operability and emissions impacts as fuel composition varies in diverse power generation devices such as gas turbines, boilers, and reciprocating engines</p>	<p>Combustion based power generation systems have been optimized to minimize emissions and maximize efficiency when operated on natural gas. In the future, renewable fuels from biomass or waste streams can be used to displace the fossil gas fuels. Efficient design of devices for these alternative fuels requires tools that can describe how fuel composition impacts operability and emissions. This requires determination of combustion characteristics such as flashback propensity, ignition delay, kinetic pathways, and flame speeds. Efficient development of a wide range of fuel flexible combustion technologies for power generation can be facilitated by design tools that describe operability and emissions impacts as fuel composition varies.</p>	<p>The tools developed can be used to accelerate development and deployment of combustion technologies to utilized fuels with a reduced CO2 impact and possibly NOx benefit. If 5% of power can be generated using renewable fuels, it will displace more than 6M tons of CO2 annually. Additionally, if the availability of these fuels reduces the price of natural gas by 0.25/1000 scf, it will save consumers more than \$564M/yr. If fuel costs can be reduced by use of opportunity fuels either by direct reduction of cost of the renewable fuel or by displacement and hence less demand for natural gas it will provide direct cost savings to customers. If the availability of these fuels reduces the price of natural gas by 0.20/1000 scf, it will save consumers more than \$450 million per year. But actual savings could be much higher.</p>

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 69	Healthy Homes - Exposure to Unvented Combustion Gases: develop the science to reduce health risks to the population of California from exposure to unvented residential combustion gases - residential natural gas appliances, with specific focus on unvented appliances and advanced technology water heaters	<p>Unvented and improperly vented combustion sources in residences, can lead to high indoor pollutant concentrations and exposures, presenting a substantial health hazard. It is well established that combustion-related pollutants reach hazardous levels in homes. Yet there is a scarcity of data that would allow an assessment of the frequency of such occurrences. As the Energy Commission establishes energy efficiency standards for existing homes, it is important that the impacts of these sources are well understood so as not to degrade indoor air quality. (Source: Energy Commission's Energy Consumption Data Management System)</p> <p>The study targets primarily unvented, improperly vented and improperly functioning appliances. It focuses on measurements of carbon monoxide, nitrogen dioxide and formaldehyde but will attempt to obtain measurements of other pollutants in at least a subset of the homes. In addition, this project is building on one prominent finding from previously PIER funded research that found tankless water heaters had emissions of carbon monoxide and formaldehyde orders of magnitude higher on average compared with storage water heaters. This finding suggests that a large shift to tankless technology could dramatically impact the emissions of carbon monoxide and formaldehyde from natural gas water heating. Additional laboratory testing of tankless water heaters is being conducted to better quantify emissions.</p>	This project will provide critical data needed to evaluate potential mitigation measures to reduce carbon monoxide, nitrogen dioxide and formaldehyde levels in homes. Including the assessment of potential health benefits of those measures and to identify co-benefits such as increased energy efficiency, reductions in other pollutants and greenhouse gases. These are qualitative benefits.
Description 70	Effect of Natural Gas Fuel Composition on Vehicle Performance and Emissions: evaluate the performance and air pollution impacts of natural gas vehicles using various unconventional natural gas blends including imported LNG	<p>As natural gas blends from a wider range of sources become more prevalent, it is important to understand the impact of natural gas fuels with different composition on emissions and performance of natural gas vehicles. Without adequate emissions and performance data, the regulations for natural gas specifications for vehicles cannot be updated, and many sources of natural gas may not be viable for use in vehicles.</p> <p>Currently, there are 20,000 to 27,000 natural gas vehicles in California. If each of these vehicles uses approximately 500 gge per year (based on traveling an average of 10,000 miles per year and getting a fuel mileage of 20 miles per gge of fuel), this represents approximately 10 million gge annually.</p>	Ensuring the natural gas fleet can continue to grow using unconventional natural gas sources: This research ensures that a wider range of natural gases (imported LNG and unconventional NG) can be used in California vehicles in a safe and environmentally sound manner. Research is being followed closely by air agencies & industry. ARB is using the results in revising the Compressed NG Fuel Specifications for Motor Vehicles. As well as the SDAPCD in preparation for the importation of LNG into their District. SCAQMD also used the results in their Final Staff Report for Proposed Rule 433 - Natural Gas Quality, May 2009. The ability to use LNG and other non-traditional NG in place of NG increases the supply of NG a maximum of 484 million cubic feet per day with current facilities. A small portion of this will be used by NG vehicles.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 71	Potential Impacts from Geologic Carbon Sequestration on Groundwater Resources in Central Valley of California	<p>Successful application of geologic carbon sequestration may allow mitigation of the impacts of hundreds of TBtUs of natural gas consumption.</p> <p>For geologic carbon sequestration to be successful, potential effects on groundwater supplies must be understood.</p>	<p>Focusing on the geological formations in the Southern San Joaquin Valley, this research project looks to mitigating GHG emissions from fossil fuel consumption and provides for continued use of fossil fuels while still meeting AB 32 goals. Natural gas currently provides more stable and steady power than intermittent renewables. This project has quantitative and qualitative benefits. The projected result of this project is storage of 5,000,000 tonnes of CO₂e per year.</p> <p>The quantitative benefits are the exploration of the effects of geologic carbon sequestration to further develop methods of carbon sequestration to mitigate GHG emissions. The findings can lead to expanded benefits in other areas outside the Southern San Joaquin Valley.</p>
Description 72	Energy Efficiency Calculator Tools: Development of Excel-based calculator tools to quantify the energy savings achieved by implementing various energy efficiency measures in process heating and steam generation	<p>Currently there is no simple method for plant operators to understand where energy is used, identify and prioritize energy savings opportunities, and assist plant management in justifying energy efficiency improvement projects. It is necessary to develop and distribute simple software tools that would help facilities in process design, optimization and performance prediction to improve energy efficiency.</p> <p>Process heating and steam generation addressed by these software tools accounts for 85% of California's industrial natural gas consumption (information from project write-up).</p>	<p>Savings from efficiency projects undertaken with the aid of these tools will vary, but 5% is a conservative estimate for savings to be achieved with individual cost-effective energy efficiency improvement projects.</p>
Description 74	Next Generation Instantaneous Water Heater: This project sought to identify any issues with tankless water heaters and discover ways to improve the technology	<p>Higher efficiency gas water heaters could offer substantial benefits but because most replacements are emergency calls without the customer having time to research options, high efficiency heaters are seldom installed. By 2015, natural gas water heaters will be required to have an energy factor of .62 (be around 62% efficient). Tankless water heaters have better energy factors up to 0.92, but they are expensive, difficult to retrofit, require regular maintenance, and potentially have some operational problems which this research seeks to address to allow a higher penetration of tankless technology. The average California homeowner uses about 193 therms/year for water heating at a cost of nearly \$200 a year. Of the 12.5 million households in California, 79% or 9.9 million have natural gas water heaters and collectively use nearly 2 billion therms/year of natural gas.</p>	<p>Assuming 12.5 million households in California and 79% or 9.9 million of those households having NG water heating, an increase in average water heater efficiency via a pure tankless heater from 0.62 to 0.92, would save 63 therms/year each or about 620 million therms/year across California.</p>

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 75	Hybrid Optimized Tankless (HOT) Water Heater: Development of a low-cost, higher efficiency, water heater, which can be easily retrofitted for the new and replacement market	Higher efficiency gas water heaters could offer substantial benefits but because most replacements are emergency calls, they are seldom installed. Tankless water heaters are most efficient but require larger diameter gas lines, making retrofits expensive and uncommon. A more affordable hybrid that uses the old gas line and has some buffer storage can achieve much higher penetration. Its energy factors range from .70 to .75, compared to the 0.62 energy factor that will be required in water heaters. The average California homeowner uses about 193 therms/year of natural gas for water heating at a cost of nearly \$200 a year. Of 12.5 million households in California, 79% or 9.9 million have natural gas water heaters and collectively use about 2 billion therms/year of natural gas.	The hybrid optimized tankless water heater offers improved efficiency by being tankless, yet its buffer system will negate the need for expensive upgrades. It also offers continuous water heating, even with low volume, that until now was only available with tanked water heaters. By increasing average water heater efficiency via the hybrid tankless heater from 0.62 to 0.73, households will save 29 therms/year or 290 million therms/year across California, assuming 5% penetration equaling 15 million therms/yr saved.
Description 76	Production and Conditioning of High Sulfur Biogas for Fuel Cell Combined Heat and Power Generation: conditioning and clean-up of high sulfur biogas produced from agricultural waste through an anaerobic digestion process	Annually, the California agricultural market generates approximately 40 million tons of waste. This waste can be utilized as a source of natural gas as well as recoverable heat. The technical objective is to clean and condition high-sulfur biogas to meet stringent fuel cell gas quality levels to displace natural gas as a fuel for two direct fuel cell electricity power plants. This will lower GHG emissions and improve energy efficiency and operating costs of the overall process.	Gills Onions, the project site, consumes approximately 50,000 tons of onion waste per year and displaces 30.6 million scf of natural gas. See also PNG-07-002 (Row 2) for the potential natural gas ratepayer benefits.
Description 77	Production and Conditioning of High Sulfur Biogas for Fuel Cell Combined Heat and Power Generation: conditioning and clean-up of high sulfur biogas produced from agricultural waste through an anaerobic digestion process	Annually, the California agricultural market generates approximately 40 million tons of waste. This waste can be utilized as a source of natural gas as well as recoverable heat. The technical objective is to clean and condition high-sulfur biogas to meet stringent fuel cell gas quality levels to displace natural gas as a fuel for two direct fuel cell electricity power plants. This will lower GHG emissions and improve energy efficiency and operating costs of the overall process.	Having successfully deployed the biogas production technology in the extremely high sulfur onion processing industry and demonstrating the benefits at Gills Onions, the technology could potentially be deployed for almost all of the agricultural systems in California, which would total 40 million tons of waste per year. This could result in the replacing of 26.5 billion scf of natural gas and 4,600 billion Btu of recoverable heat. In addition clean, distributed biogas production could potentially reduce CO2 emission by 13 million tons per year (worth \$260 million at \$20/ton) as well as provide cost stability by using agricultural waste for biogas production.

Benefits Calculation Description	Project	Issue or Opportunity	NG Ratepayer Benefits
Description 78	Reducing California Industrial Natural Gas Consumption Through Advanced Biomass Gasification: demonstration of an advanced, lower-cost molten-metal gasifier that can utilize waste biomass to create thermal energy for mid-sized industrial concerns	Thermal process energy is one of the highest cost inputs for medium scale industrial plants, such as wallboard plants, pulp/paper operations, and general industry in California.	In California, up to 969 million therms of energy could potentially be replaced annually by this technology, using waste products to replace purchased natural gas, if fully deployed.
Description 79	Advanced Residential Energy and Behavior Analysis Project: residential natural gas demand forecasting models and energy efficiency programs and policies	Accurate data and information does not exist that captures the behavior and choices of residential natural gas consumers. Residential consumer behavior can result in a 200 percent or more difference in consumption in identical buildings under the same weather conditions.	Understanding behavior and reducing the 200 percent or more variability in consumption will allow for more accurate demand forecasting models, reducing system costs, as well as more effective energy efficiency policies and programs such as addressing people's thermostat understandings and behaviors. It would not be surprising for better designed programs to lead to a 10% drop in natural gas use. One can expect at least a 2% drop - the number applied in estimating benefits. In addition, ratepayers will benefit by having energy and money saving options that are in-line with what they actually want, and programs and policies that are relevant to them, as opposed to the non-existent "typical" residential consumer.